TEXT-BOOK
OF
HYGIENE BASED ON PHYSIOLOGY
FOR
SCHOOL TEACHERS

A. WATT SMYTH

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THE PRINCIPLES OF HYGIENE

A TEXT-BOOK

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THE PRINCIPLES OF HYGIENE BASED ON PHYSIOLOGY

FOR THE USE OF SCHOOL TEACHERS

BY

A. WATT SMYTH

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INTRODUCTION.

THIS work places in the hands of teachers, for the first time, a text book of hygiene founded upon physiology. Hitherto these subjects have been treated independently of each other in separate works, and the student has had to find out as best he could the connexion between the two divisions of what is in reality a single subject. Physiology is the science of the action of the body in health, hygiene the practical application of this science: it is obviously impossible to understand the laws of hygiene without a knowledge of the fundamental principles of physiology. A reasoned knowledge of these subjects will be of threefold use to the teacher: (1) to guide him in the management of the children under his care; (2) to supply him with the knowledge required to manage his schoolroom hygienically; (3) to enable him to teach personal and domestic hygiene to the scholars.

Teachers in public elementary schools have a number of serious responsibilities with regard to the mental, moral and physical welfare of the children under their charge, and they are not justified in undertaking these without guidance.

Next to infancy, school-age is the most important period in the life of a human being: it is the period of growth and development. School conditions involve the confinement of children in crowded rooms for many hours a day, and are necessarily unfavourable to the natural healthy development of the body. The aim of the teacher should be to modify and counteract these unhealthy conditions by every means in his power. With him rests the drawing out of the school programme, and in doing this he will first of all consider the requirements of the normal healthy child.

No hard and fast rule can be laid down, because children vary so much in physique and intelligence in different neighbourhoods. In a district where the parents are very poor and squalid, the standard at a given age will be much lower than that in a pros-

perous one, for in underfed, neglected and diseased children mental development is retarded.

The teacher will have to use his judgment in singling out for special schools children who, from mental or physical causes, are so far behind the normal standard as to be a hindrance to the normal child, while themselves unable to profit by the teaching in an ordinary elementary school. It will be his duty to differentiate between the curable and the hopelessly defective; he will have to single out the imbeciles, the deaf, the mouth-breathers, the blind, the epileptic, the starving, or those suffering from nervous disorders.

School conditions, especially in schools where dinners are given to the underfed through some benevolent influence, are often so much better than home conditions, that many children, who appear at first sight hopelessly deficient, improve rapidly and make as much progress as those who seemed more promising. The teacher cannot conscientiously deal with the collections of children forced to attend school, until he understands the laws that govern the growth of the brain and nervous system generally, and the effects of physical exercises on the nervous and muscular systems. He ought also to have a knowledge of the natural history of the diseases common in childhood.

These subjects have been dealt with, and it has been thought advisable to describe in detail the effects of the exercises in the *Syllabus* of physical exercises, upon the muscles brought into action by them. Hitherto it has been considered sufficient to present a syllabus without any explanation of the educational effects of the exercises.

All teachers are obliged to pass the South Kensington examination in hygiene and physiology, or an examination equivalent to it, before they were qualified to teach physical exercises to their classes. No one will deny that the theory of exercise should be well understood by those who have to train physically, young, developing children. But that the object of the examination is not fulfilled is only too apparent to anyone who watches the aimless mechanical movements of a class at work, and by the answers to the examination papers. It is hoped that this book will assist students to understand that every movement has for definite aim the exercising of some particular muscle or set of muscles, and that, unless

carefully chosen and intelligently and energetically done, they will fail to counteract the bad effects of confinement in school.

The subject of digestion and food has been dealt with at considerable length, because it is felt to be of the first importance. Not only is there great waste of money in buying unsuitable food and cooking it badly and extravagantly, but the unpalatable quality of the food is one of the chief causes of the craving for alcohol in the labouring classes.

The book will supply to teachers the information necessary for them to follow out the advice contained in the chapter on The School and the Health of the Scholars contained in the volume of *Suggestions for the Consideration of Teachers and others concerned in the Work of Public Elementary Schools*, 1905, issued recently by the Board of Education.

While using this text book as a basis for their schemes of instruction, teachers are advised to draw upon their own experience and judgment in the application of the principles set forth. The popular idea that hygiene is a science dealing with that part of medicine which aims at the preservation of health is too narrow. It should rather mean the material and moral improvement of man as an individual and as a citizen—in a word, progress.

I am greatly indebted to Miss Turner, Inspectress of Elementary Schools in London, for giving me much practical advice, and for enabling me to visit a number of typical schools where I was encouraged by the sympathy of Head Teachers, all of whom desired to see hygiene taught in Elementary Schools. I am also indebted to Dr. Dawson Williams for assisting me in some of the more technical parts of the book, and to Mr. S. G. Shattock, F.R.C.S., of the Museum of the Royal College of Surgeons of England, for helping me to obtain the photographs and skiagrams from which the Plates have been made. Lastly, I wish to express my general indebtedness to the annual reports of Dr. Kerr, Educational Medical Officer for London, which contain many valuable suggestions with regard to the hygiene of schools and the protection of the health of the children attending them.

A. W. S.

I.—THE TISSUES.

The Place of Man in the Animal Kingdom—The Cell and its Properties—Epithelium—Connective Tissue—Serous Membrane.

Vertebrate animals, distinguished by the possession of a vertebral or spinal column enclosing and protecting the spinal cord, form the highest group of the animal kingdom. The mammals, that is, animals which suckle their young, are the highest group of the vertebrates. Man, distinguished from the anthropoid apes, the animals which most closely resemble him, by the large size and complex structure of his brain, is the highest of the mammals. Everything which distinguishes him from the brutes is related to this unique peculiarity. The nervous system of man, owing to the complexity and perfection which it eventually attains, takes many years to develop. This is the chief reason why he reaches maturity at a much later age than most other animals; they, as a rule, have died of old age before man has stopped growing.

During these long years of growth and development through infancy, childhood and adolescence, the growing organism is influenced, for good or evil, by conditions of environment which have relatively little effect on the adult. School teachers, controlling as they do so much of the time of growing children, and entrusted with the responsibility not only of imparting knowledge but of training them in good methods and habits, ought themselves to understand the main facts about the structure and the functions of the body, and the laws by which its healthy growth is governed.

The Cell.

The simplest form of living organism consists of a single cell. The amœba, for instance, which leads an independent life in stagnant water, is a single cell. It consists of a minute mass of jelly-like living material called protoplasm. It is capable of movement, and feeds by taking particles into its substance. In the centre of the protoplasm is a specialised portion called the

nucleus. Cells presenting a close general resemblance to the amœba are essential constituents of the blood of the highest animals, including man. In the process of growth the tissues are built up by simple cells modified to suit the particular purpose they are to serve. Thus one set of cells forms the bones which support the body; another set the muscles which act upon the bones and so produce movement; another set forms the brain, spinal cord, nerves and the organs of sense, which together make up the nervous system; through the nervous system we receive impressions from the external world and direct and control the movements of the body; other cells again develop into the alimentary canal, into which food passes and is digested; others again form the circulatory system, and through this the blood, which consists of cells floating in a fluid, is distributed throughout the body. The cells constituting these various systems are all living and continually active. All living cells have certain common characteristics: they all possess the powers of assimilation, irritability and reproduction.

Assimilation and Disassimilation.

By assimilation is meant the power of taking into itself nutriment from the blood and changing it into living substance. To do this the cell requires water and oxygen, both also derived from the blood; further, the cell is able to get rid of waste products which are carried away by the blood, a process called disassimilation. By irritability is meant the power of responding to influences reaching the cell either from the external world or from the nervous system. A simple instance is the case of an amœba coming into contact with a floating particle of vegetable matter. The contact acts as a stimulus to the protoplasm of which the amœba is composed; it begins to move round the particle and finally engulfs it. As a more complex example may be instanced the contraction of a muscle which follows the stimulus afforded by the arrival, through its nerve, of an impulse from the brain.

Reproduction.

The cell has the power to multiply by division. This process commences in the nucleus; it separates into two distinct parts, which move to either end of the cell; the protoplasm between

them then divides, and two cells are thus produced which exactly resemble the original.

During the growing period, when the organs are increasing in bulk, the multiplication of cells is rapid; but when growth has stopped, they are in health only produced in numbers sufficient to replace those which are worn out. In inflammatory diseases certain cells are often reproduced in large numbers, as is explained in the observations on the reaction of the body in the section on infectious diseases. Cancer is produced by a rapid and disorderly production of cells in the part affected; why this occurs is still a mystery.

Epithelium.

All the surfaces of the body, internal as well as external, are lined by a protective layer of cells, modified in different parts for different purposes. This tissue is called epithelium, and the cells of which it is composed epithelial cells. The special characters and powers of the epithelial cells in various situations will be discussed in the description of the various organs of which they form part.

Connective Tissue.

Connective tissue is the term applied to the tissue which connects the organs of the body and the parts of different organs together. In its most typical form it consists of tough, white opaque fibres, sometimes running side by side, sometimes interlacing. Tough sheets of this fibrous tissue envelop the muscles, bind them together and give a smooth regular contour to the limbs and trunk. The ligaments of the joints are formed of fibrous tissue. In places the fibrous tissue contains a larger or smaller proportion of elastic fibres which have a light yellow colour. In some situations there is more or less fat among the fibres; this may be a deformity as in obesity, or may be a natural and necessary provision for safety and ease of movement, as is well exemplified in the orbit, where the eye is supported by a packing of soft fat.

Serous Membrane.

A serous membrane is a thin fibrous sheet, with smooth glistening surface, lined by flattened epithelium. Internal organs which must have a certain freedom of movement, the lungs,

heart and intestines, for instance, are covered by a sheet of serous membrane turned up or reflected on to the surface with which the organ would otherwise be directly in contact. A general idea of a serous membrane may be obtained by taking a closed sponge bag and folding it over the fist. The hand represents the internal organ or viscus, the side of the bag in contact with the hand represents the visceral layer of the serous membrane, the other side of the bag the layer of serous membrane applied to the wall of the cavity in which the organ is contained, or parietal layer, while the indiarubber lining the two sides of which are in contact, represents the smooth surfaces of the serous membrane. These two surfaces are just moistened by a little serous fluid, and the whole arrangement is designed to prevent friction. The membrane consists of a thin layer of connective tissue covered by a fine layer of pavement epithelium. Its surface, which is smooth and glistening, secretes the serous fluid that lubricates adjoining surfaces and prevents friction. The lungs, for instance, are in constant motion upon the thorax, but we are unconscious of this because the serous membrane, called the pleura, covering the lung slips easily and without friction over the similar membrane covering the inner surface of the ribs. If this membrane is inflamed it becomes rough, and the friction causes acute pain; the first symptoms of pleurisy, for instance, is a severe stitch in the side.

The structure of other tissues, such as the muscular and nervous, will be more conveniently considered when describing the systems of which they form the functional part.

II.—THE SKELETON.

General Characters of the Human Skeleton—Classes of Bones—Structure of Bone—Development of Bones—Shaft and Epiphyses—Joints—The Spinal Column—The Thorax—The Skull—The Upper Limb and Hand—The Pelvis—The Thigh—The Leg and Foot.

The highest group in the animal kingdom is called the vertebrate, because all its members possess a spinal or vertebral column. There is a general resemblance in the skeleton of all vertebrates. but it is modified in many interesting ways in relation to the habits of the different animals. The peculiarities of the skeleton of man, the highest of the vertebrates, are determined chiefly by his two striking characteristics: his erect attitude and large brain.

In describing the parts of the body, it is customary to state their position in relation to an imaginary line drawn from head to foot through the middle of the body. An organ is said to be inside or internal to another when it is nearer this imaginary middle line; it is anterior if in front, posterior if behind the line.

The skeleton gives general form to the body, and in the adult is composed almost entirely of bone with, in certain places, cartilage. In childhood many of the bones are still imperfectly formed, and consist largely of cartilage, which is soft and easily deformed. The human skeleton contains no less than two hundred and six distinct bones.

Structure of Bone.

Bone is either compact or spongy in structure. Compact bone is hard like ivory, and forms the outer surface of all bones. The interior of most bones is formed of spongy tissue, which is everywhere permeated by red marrow. The shaft of a long bone, however, is made up almost entirely of compact substance; the hollow centre is filled with yellow marrow.

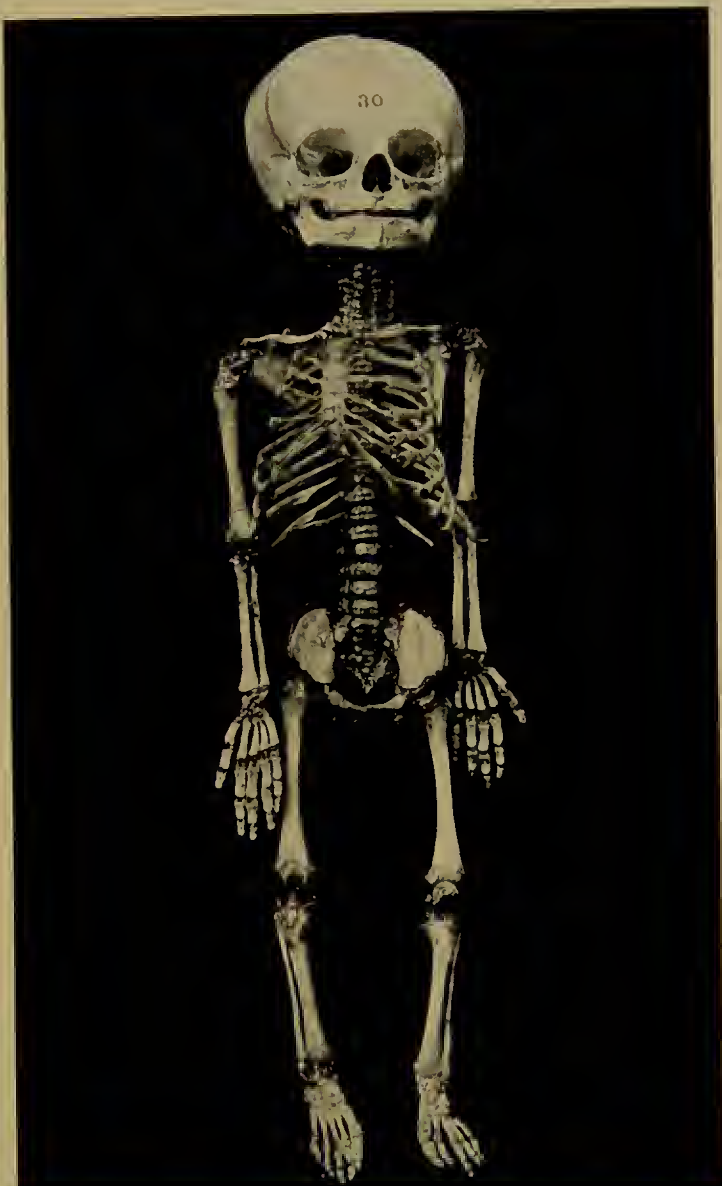
For convenience, three kinds of bones may be distinguished:
1. The long bones, generally with cylindrical shafts and joint ends,

PLATE I.

SKELETON OF A NEWLY-BORN INFANT. (*Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

Note the large size of the cranium in relation to the rest of the skeleton, and also that the wrists and ankles, and the ends of many of the bones are cartilaginous.

Plate I.



Skeleton of Infant.

as in the limbs; 2. The short bones, composed of spongy tissue, with a thin crust of compact tissue, such as the bones of the wrist and ankle; 3. The flat bones, consisting of two thin layers of compact tissue enclosing a layer of spongy tissue; for example, the bones of the skull. A fourth class may be made for irregular bones, such as the vertebræ.

Every bone is covered by a thin, fibrous membrane, the periosteum, which is of great importance in the growth and nutrition of the bone, and in its repair after a fracture. On the surface of bones many small holes may be seen: these are the apertures of channels through which the blood vessels from the periosteum pass to the bone and the marrow.

From looking at prepared dried skeletons in a museum, we are apt to get the idea that a bone is a dead or non-living structure. This is very far from being the case. Even in the adult when growth has ceased, a bone is the seat of very considerable vital activity; it has an ample blood supply, and even the hardest bone is traversed in every part by blood vessels which run in minute canals; these canals contain nerve filaments also. The bone substance is arranged in concentric layers round the canals, and in minute spaces between the layers are living cells, the bone corpuscles, whose fine branches traverse the bony substance in every direction. The red marrow in the spongy bones, and in the spongy part of the long bones, is very copiously supplied with blood vessels and it is here that new blood corpuscles are formed to supply the place of those which are constantly being destroyed in various parts of the body. In the child, the life of a bone is still more active, for in addition to the processes occurring in fully formed bone, active growth, both in length and thickness, is going on.

Growth of Bone.

At birth the skeleton is only, so to say, a sketch of what it is to be. The skull is still largely composed of membrane, and such bone as is formed is thin and easily indented. The shafts of the long bones are ossified, but their ends are still cartilage; the wrists are entirely, the ankles almost entirely cartilaginous, and the hip bones also consist mainly of cartilage (see Plate I.).

Every teacher should have a knowledge of the way in which

PLATE II.

Vertical Section of the Knee Joint (through the lower end of the femur and upper end of the tibia and fibula), and also of the Ankle (through the lower end of both bones of the leg), to show the Epiphyses and Epiphysial Lines. (*Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

T, Femur (E its epiphysis); S, Tibia (E,E its epiphyses); F, Fibula (E,E its epiphyses). The cartilages lying between the shafts and epiphyses of the bones show clearly as white irregular lines, and the thicker cartilages covering the joint surfaces are also well seen. Note the longitudinal arrangement of the laminæ of the shafts of the bones. (From a child aged 15 years.)

Plate II.

Epiphyses of Knee and Ankle ·

bones are formed and grow in size, for the skeleton is developing throughout the whole period of childhood and adolescence, and is, in fact, not quite complete until the twenty-third or even the twenty-fifth year.

All bones are formed in soft tissue by a process called ossification, the chief feature of which is the deposition of earthy salts according to a well-defined plan. In most bones ossification takes place in cartilage; that is to say, the true bone is preceded by a cartilage having more or less the same form. The cartilage, like the bone it precedes, is covered by a membrane (periosteum), and bony tissue develops under this membrane as well as in the substance of the cartilage. A bone increases in length by ossification in the cartilage, in thickness by ossification under the periosteum. The development of true bony tissue in a long bone begins at one point in the shaft, called the centre of ossification; after growth has gone on to a considerable extent from this centre, two other centres usually form at either end near the joint. The ends of the bone and the joint surfaces are formed from these two secondary centres of ossification. There is thus a stage in which a long bone consists of at least three parts, a bony shaft and two bony ends, with a thin layer of cartilage between the shaft and each of the ends. The two detached bony ends are called the epiphyses, and the layer of cartilage between them and the shaft the epiphysial line. Eventually the epiphysial line disappears and the epiphyses become one with the shaft: when this has happened no further growth in length can take place.

The condition of things before this occurs is well seen in Plate II., showing the bones of the knee-joint at the age of fifteen years. The shafts of the bone have been cut short, and the joint has been divided vertically so as to show the epiphysial lines of the femur (T), and of the tibia (S), as well as the interior of the knee-joint. It will be seen that the epiphyses are entirely separated from the shaft by the layer of epiphysial cartilage which shows white in the photograph. Where the shaft and the epiphysial cartilage join new bone is constantly being formed, and it will readily be understood how this must lead to a gradual elongation of the shaft of the bone; at the same time the epiphysis itself is growing to keep pace with the shaft.

In an adult a bone, subjected to a severe strain or blow, breaks across like a dried stick; but in early childhood the ossification is less complete, and the bones are less brittle, so that a bone may not break right across but crack on one side and bend on the other like a green stick; such injuries are called "green stick fractures." A more common accident is separation of the epiphysis from the shaft at the epiphysial line; this, owing to the importance of the cartilage at the line, is a rather serious matter, for if not skilfully treated it may lead to much deformity.

A joint is the point of junction between two bones or between a bone and cartilage. Anatomists usually employ the term articulation, from the Latin word *articulus*, a joint: it must be remembered that Vesalius and the other great anatomists of the Renaissance, who founded the modern science of anatomy, wrote in Latin; the terms used by them have been to a very large extent retained, and the system has the advantage that anatomical terms in English, French, Italian and Spanish are the same, or so little modified, that they can easily be recognised. Many parts of the body have also old English names, but the student is recommended to become familiar also with the more common Latinised forms used in this book.

There are two main sorts of joints, (1) those with a true joint cavity where movement is free, as, for instance, the shoulder, knee and other joints of the limbs, and (2) those in which there is no joint cavity, and either very limited movement or none at all; examples are the joints between the vertebræ, in which movement is in most instances very small, and those between the bones of the skull, which are immovable, and fit together like a Chinese puzzle. A fixed joint is termed a suture.

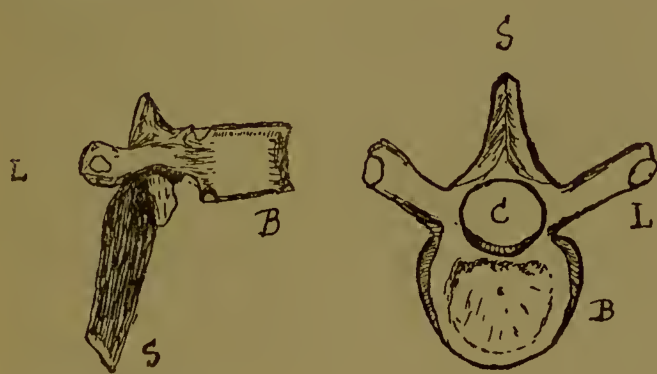
The Spinal Column.

The spinal or vertebral column consists of thirty-three bones, vertebræ, fitting together one above the other. Viewed from the side as a whole, it is seen to be curved forward in the neck, backward in the back, and forward in the loins (Plate III.). The twenty-four upper vertebræ are movable to a greater or less extent the one upon the other. The freedom of movement, backward stretching, forward bending and rotation, is greatest in the neck. In the

back movement is very limited, but it is freer again in the loins. The lowest nine vertebræ are fused together in the adult into two bones, five into the sacrum, which forms the back of the pelvis, and the last four into the coccyx, which represents the tail of the lower animals. In childhood, the bones of the sacrum are separate; they are formed in cartilage, there being separate centres of ossification for each of the five vertebræ.

The spinal column is the organ of support for the trunk, and of protection for the spinal cord, and is the axis or pivot upon which the head and body turn. Upon it the other parts of the skeleton are arranged. At its upper end it supports the skull, at the sides the ribs through which it receives the weight of the upper limbs, while the weight of the trunk is transmitted to the lower extremities through the sacrum.

The movable vertebræ differ in form in different parts of the column, the differences being traceable chiefly to variation in the degree of mobility.



From the right side. From above.

Fig. 1.—Dorsal Vertebra (Adult).

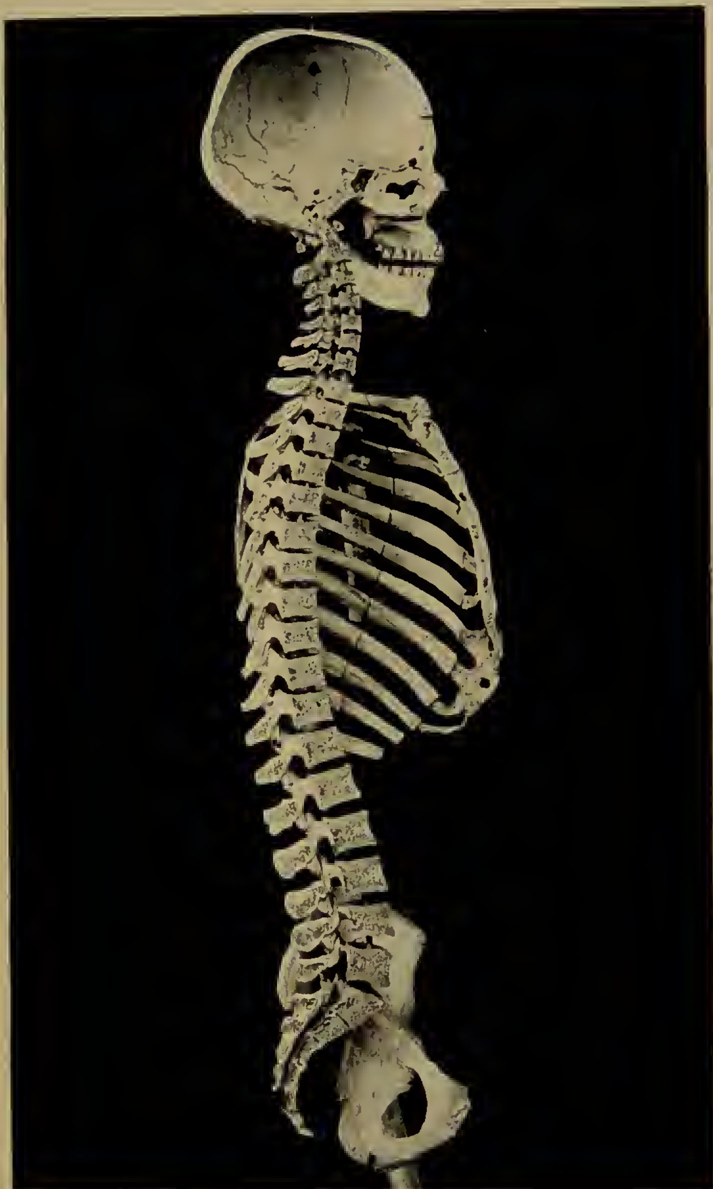
B, body ; S, spinous process ; L, transverse process ; C, spinal canal.

Each vertebra consists of a body in front, and of an arch or ring behind (Fig. 1). From the middle of the back of the arch springs a bony projection, the spinous process. The tips of these processes can be felt in the middle line of the back, one below the other. From each side of the arch, near where it joins the body, projects another bony process, and to these the great muscles

PLATE III.

SKULL, SPINAL COLUMN, THORAX AND PELVIS. (*Photograph of an adult specimen in the Museum of the Royal College of Surgeons of England.*)

The skull and spinal column have been divided down the middle line to show the cranial cavity and spinal canal. The ribs and collar bone, and the hip bone on one side, are shewn, and also the cut edge of the breast bone (sternum). The posterior edge of the blade bone can be seen behind the upper dorsal vertebræ, and the upper parts of the arm bone (humerus) and thigh bone (femur) behind the thorax and hip bone respectively. Note the threefold curve of the spinal column, forward in the neck, backward in the back, and forward in the loin, and the final backward curve of the sacrum. Note also the variations in the size of the bodies and the shape of the spinous processes of the vertebræ.



Skull, Spine, Thorax and Pelvis.

which straighten the back are attached. The body is a thick disc with a rounded front, and flat upper and lower surfaces; between these surfaces lie the intervertebral cartilages or discs which make an elastic connection between one vertebra and those above and below. The vertebræ are so arranged one above another, that their arches form a tube, extending from the skull to the coccyx (Plate III.), in which the spinal cord and the beginnings of the spinal nerves are contained.

The vertebræ of the neck (cervical vertebræ), seven in number, are smaller and lighter than the dorsal, and their bodies are thin. The first, which carries the weight of the head, is called the atlas: it has practically no body, but a large arch slightly smaller in front; this smaller part is formed into a ring by a ligament stretched from side to side. The second vertebra, called the axis, is the pivot on which the atlas rotates when the head is turned. The upper part of the body of the axis projects upwards into the ring of the atlas. On the upper surface of the atlas are two large articulations for the occiput. The seventh or last cervical vertebra has a very long spinous process which projects prominently at the back of the neck, and is therefore often called the vertebra prominens.

The vertebræ of the back (dorsal vertebræ) are twelve in number. Their spines are directed downwards, and overlap each other like the tiles on a roof, as may be seen in Plate III. It is with these vertebræ that the ribs articulate.

The vertebræ of the loin (lumbar vertebræ) are larger than the dorsal, their bodies thicker, their arches stronger and their spinous processes more horizontal (Plate III.).

The ossification of each vertebra starts from three centres, one for the body and one for each side of the arch with its processes. At birth each vertebra consists of three irregular masses of growing bone imbedded in a cartilage which has approximately the form the fully formed bone will eventually possess. The growth of the bony substance goes on throughout childhood, and it is not until the age of 14 or 15 years that the vertebræ are perfectly formed. It needs no argument to prove that deformities of the spine are very easily produced by faulty attitudes in sitting or standing in childhood, while the bones of the spinal column are still so imperfectly formed, and consist to so large an extent of soft and yielding cartilage.

In addition to the discs of cartilage existing between their bodies when fully formed, the vertebræ are bound together by strong fibrous bands which pass from the processes to the corresponding parts of the next vertebra above and below. Owing to the elasticity of the intervertebral cartilages jarring is diminished, and the back can be bent and straightened.

The Thorax.

The skeleton of the chest or thorax is formed by the ribs, twelve on each side, jointed behind to the twelve dorsal vertebræ. The ten upper ribs curve outwards and forwards to join either directly or indirectly the sternum or breast bone (Plate III.). Each of the seven upper ribs is joined to the sternum by a strip of cartilage. These rib-cartilages vary in length, that belonging to the first rib being the shortest, and that to the seventh the longest; the eighth, ninth and tenth ribs end in strips of cartilage that join the cartilage of the rib immediately above. The eleventh and twelfth are not attached in front but end free, and are therefore called floating ribs. The ribs are themselves very elastic bones, and the elasticity of the thorax as a whole is increased by the rib-cartilages, The thoracic cavity has the shape of an irregular cone with the apex upwards; that is to say it is wider below. It is also broader from side to side than from front to back, and much longer behind than in front.

When at rest, at the end of an expiration, the ribs slope downwards; when a breath is taken they are pulled up in front and turn on their joints with the vertebræ. As will be understood on consideration, or better by examination of an articulated skeleton or a model of the chest, the raising of the ribs increases the capacity (size) of the thoracic cavity by, as it were, opening it out.

The Skull.

The skull consists of the cranium or brain case and the bones of the face. With the exception of the lower jaw, all the bones are firmly united together in the adult by uneven toothed edges, and the lines of articulation are termed sutures.

The special characteristic of the human skull when compared with that of other mammalian animals, is the large size of the

cranium in relation to the rest of the body and in relation also to the face. The size of the cranium depends, of course, upon that of the brain. As will be more fully explained in the section on the nervous system, the size of the brain in infancy is, proportionately to the rest of the body, much greater than in an adult, and the size of its cranium corresponds. The face, however, is not out of proportion to the rest of the body, and in the skeleton it appears small in proportion to the cranium. Both these points are well shown in Plate I. of the skeleton of an infant, preserved in the Museum of the Royal College of Surgeons of England. During childhood the whole skull enlarges rapidly, and the face, as it were, grows up to the cranium until in the adult it forms about half of the bulk of the whole skull, whereas at birth it forms only about one-eighth. All through childhood the relatively large size of the cranium is remarkable, and this is well shown in the two photographs on Plate IV. taken to the same scale; A is a front view of the skull of a child aged 5—6 years; B that of an adult. The breadth of the child's skull behind the temples is to be noted, whereas it will be observed that the breadth of the forehead is relatively greater in the adult, owing partly to the increase in the bulk of the front part of the brain. The chief point to remark is that the brain-case is almost as large in the child as in the adult: in fact, in these particular skulls the child's is broader than the adult's. The significance of this is discussed in the section on the nervous system. The relative increase in the size of the face is, in the main, due to the development of the jaws by the growth of the teeth, and to the formation of a large air cavity in the upper jawbone.

The cranium, which forms the case for the protection of the brain, is a vaulted dome with an irregular, more or less, horizontal base. At birth the bones are thin and the sutures, for the most part, have not yet been formed, the bones being joined by membrane. At certain places these gaps, filled only by membrane, are easily felt. They are called fontanelles. The largest is at the crown, at the point where the two parietal bones meet the two halves, not yet united, of the frontal bone. It is called the anterior fontanelle and does not close until the second year. In a ricketty infant the closure may be delayed until much later. There is usually another

PLATE IV.

A.—Skull of a Child aged 6 years. (*Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

To be compared with **B**, photographed on the same scale.

Note the large size of the vault of the skull in relation to the face, and the lines of articulation between the nasal, upper jaw, and malar bones. The front part of both the upper and lower jaw has been cut away to show the permanent teeth developing in the jaws. (Some of the milk teeth have been lost.)

B.—Skull of an Adult. (*Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

To be compared with **A**, photographed on the same scale.

Plate IV.

A B

Contrasting Skull of Child and Adult.

smaller posterior fontanelle in the middle line where the two parietal bones join the occipital bone.

There are eight cranial bones, one in front, one behind, two at each side and two at the base. The dome or vault is made up of the frontal bone which forms the forehead, the parietal bones forming the crown and the greater part of the sides, the temporal bones, which complete the sides, and the occipital bone forming the back. A large part of the base is constituted by the sphenoid bone, which also forms a small part of the sides in front. This bone, very complicated in its structure, consists of a body, two wings and numerous processes. It presents a general resemblance to a bat or a butterfly with a large body. The base is completed by the ethmoid (sieve-like) bone, which enters also into the formation of the orbits and the nose. It is an irregular cube, and consists of a central vertical plate and two lateral masses, united by a thin plate called the cribriform plate, perforated by a great number of holes, like a sieve: through these holes pass the branches of the nerve of sme (olfactory). This bone articulates with no less than thirteen other bones of the cranium and face. The sphenoid and ethmoid bones are preceded by cartilages of the same shape, and the bones are not completely formed until the fourth or fifth year.

The frontal bone forms the whole of the forehead and also the upper part of the orbits. It develops in membrane from two separate centres of ossification, one on each side, and the union into one bone does not take place until the second year. At about the same time two cavities, called frontal sinuses, begin to form in the bone just above the orbits, and the shape of the forehead depends far more on the size these cavities attain than on that of this part of the brain. The frontal bone articulates with the parietal bones at the back, with the sphenoid and ethmoid bones at the base, and with four of the bones of the face on each side.

The two parietal bones form the greater part of the sides of the cranium. They articulate with the frontal bone in front, with the occipital bone behind, with the temporal and sphenoid bones below, and with each other in the middle line. They are formed in membrane, there being one centre for each bone. The growth of bone is so rapid at these centres that they form two eminences conspicuous all through early childhood.

The occipital bone, shaped somewhat like a scallop shell, articulates in front with the two parietal bones. At its lower part there is a large oval opening called the foramen magnum, through which the spinal cord passes into the spinal canal. On either side of the foramen is a long oval projection called the condyle, which articulates with the upper surface of the atlas, forming the joint between the head and neck. The occipital bone is ossified from four centres, and at birth consists of four separate bony pieces united by cartilage; these, for the most part, have become joined by bone at about the sixth year, but the bone is not completely ossified until after twenty.

The temporal bone consists of three parts: the squamous, mastoid and petrous, which at birth are separate, being united only by cartilage. The squamous portion is a thin, curved plate, forming the lower part of the side of the skull. The mastoid portion, rough externally, projects downward to form the mastoid process, which can be felt immediately behind the ears. It is not solid, but contains cavities communicating with the middle ear. The petrous portion is so named from its hardness (πέτρος, a rock). It is a three-sided pyramid, two of the surfaces being in the floor of the skull; the structures of the internal ear are contained within this part of the temporal bone.

The Face.

The face contains six pairs of bones and two single bones.

The upper part of the face is formed chiefly by the right and left *upper jaw bones*, containing all the teeth of the upper range. They form also the floor of the orbit, the floor and outer wall of the nose and the front part of the hard palate; the greater part of the orbit is completed on the outer side by the *malar bone*, which forms the prominence of the cheek (*mala*, the cheek). The lines of articulation between the malar bone and the frontal bone and upper jaw, and between the two latter, can be seen in the photograph (Plate IV.). The antrum, a large cavity in the upper jawbone communicating with the nose, is very small at birth; it enlarges gradually during childhood, separating the two horizontal pieces of bone forming the floor of the orbit and the hard palate respectively. The hard palate is completed behind by the two

palate bones (right and left) which also help to form the back part of the wall of the nose. The bridge of the nose is formed by the two triangular nasal bones well seen in Plate IV. The rest of the nose is formed by the two nasal cartilages attached to the lower border of the nasal bones.

The lachrymal bones, small, delicate, almost square, form part of the inner angle of the orbit.

The vomer or ploughshare bone forms the back part of the nasal septum, which divides the cavity of the nose into right and left parts.

The turbinate bones, of almost papery thinness, form convoluted surfaces inside the nose on each side and are covered by the nasal mucous membrane.

The lower jaw, or inferior maxilla, is horse-shoe shaped, and contains at its upper edge the sockets for the lower teeth. The front of the bone, from the chin to the angle of the jaw, is called the body. The vertical portion above the angle called the ramus terminates in two projections, the condyle and the coronoid. The condyle forms, with a smooth surface on the temporal bone, the joint of the jaw. The two bones are not in contact, for between them is a thin plate of cartilage, so that the joint is really double. To the coronoid process of the lower jaw is attached the tendon of the temporal muscle, one of the chief muscles of mastication. The lower jaw at birth consists of a right and a left half united by fibrous tissues, bony union taking place during the first year. At birth, the body of the jaw is shallow, and the angle very obtuse; as the teeth develop the body becomes deeper, and the angle more nearly a right angle.

The Upper Limb.

The upper limb consists of the arm, forearm, wrist and hand (see Plate VI.); it is connected with the trunk by the shoulder girdle. The shoulder girdle is formed by the collar bone (clavicle) and the blade bone (scapula), which meet at the tip of the shoulder.

The *clavicle* is curved like the italic letter *f*. It extends across the chest above the first rib from the top of the sternum to the scapula. It supports the arm and scapula, keeping them in position and protecting the large blood vessels and nerves as they pass from the chest to the neck and arm. The collar bone is ossified from

PLATE V.

SCAPULA (POSTERIOR SURFACE) OF A CHILD AGED 12 YEARS. (*From a Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

A, Acromion process, forming with the outer end of the clavicle the shoulder; note the epiphysis; **S**, Spine of the scapula; **H**, Articular surface for head of humerus.

Scapula.

one centre, and the shaft is fairly well formed at birth, but there is a tip of cartilage at each end. An epiphysis forms at the sternal end at about eighteen years of age, but is not firmly united until twenty-five.

The blade bone or *scapula* (Plate V.) is the flat triangular bone at the back of the shoulder covering the upper ribs. Across the upper part is a ridge called the spine ; it projects outwards to form the acromion process with which the outer end of the collar bone articulates. The upper and outer corner of the triangle is thick and rounded, and on this rounded portion there is a shallow cup with which the arm bone articulates to form the shoulder joint. The scapula is held in place partly by the clavicle and partly by strong muscles which attach it to the spine and ribs. At birth, only the blade and part of the spine are ossified ; the bone is developing all through childhood, and the acromion process only begins to ossify at fourteen or fifteen years of age.

The arm contains one long bone, the *humerus*. Its shaft is an almost perfectly rounded cylinder. The upper end swells out into a large rounded head, which articulates with the blade bone forming the shoulder joint; the joint is completed by a loose, bag-like ligament, and the head of the humerus is held in position, not by the strength of the ligament, but by muscular action and atmospheric pressure. The humerus is flattened out at its lower extremity, and presents two joint surfaces; with these the bones of the forearm articulate. On the inner side is a projection called the internal condyle, behind which passes a large nerve (ulnar). The painful sensation produced when the elbow is knocked is due to this nerve being jarred against the bone. The shaft of the humerus is ossified at birth, but the ends are cartilage. An epiphysis, which forms the upper part of the bone including the head, begins to form during the second year, and is completed about the fifth year, but is not united to the shaft until the twentieth year, so that the condition shown in Plate VI. persists all through childhood and youth. The epiphysis of the lower end ossifies very slowly; it is not complete until the thirteenth or fourteenth year, and does not unite with the shaft until about three years later.

The forearm contains two long bones, the radius on the outer and the ulna on the inner side.

The *radius* is a long bone with a small upper and a broad lower extremity. It has a round disc-shaped head like a thick coin which articulates with the humerus by a joint allowing very free rotation. The lower broad and thick extremity of the bone articulates with the first row of wrist bones. The shaft of the radius is ossified at birth. There is an epiphysis at the upper and lower ends ; they do not unite with the shaft until the eighteenth and twentieth years respectively.

The *ulna* is a long bone with a large upper and a small lower extremity : at the front of the upper end is a large curved joint surface, called the sigmoid cavity, and this articulates with the humerus. At the back is a large, strong, angular process, the olecranon, which forms the point of the elbow. The ulna is ossified in the same way as the radius.

The wrist (*carpus*) is formed by eight small bones of irregular shape, arranged in two rows, upper and lower. The bones are held in place by ligaments, and where they are in contact with each other there are joints that allow a slight gliding or slipping movement. The wrist is entirely cartilaginous at birth. Each bone is ossified from a single centre, appearing at various ages from one to twelve years (Plate XI.).

The hand consists of the palm and fingers. The bones of the palm (*metacarpus*) are five in number. Each has a shaft and two extremities, reproducing in miniature the characters of a long bone. They articulate at the one end with the lower row of wrist bones, and at the other with the first bone of a finger or thumb. The fingers (*phalanges*) each have two short shafted bones and a terminal phalanx. The thumb has only one shafted phalangeal bone and a terminal phalanx. The shafts of the metacarpal and phalangeal bones are ossified at birth, but the ends are cartilaginous. The epiphyses begin to ossify at three to five years old, and unite to the shaft at about twenty (Plate XI.).

The Pelvis.

The pelvis is the strong bony basin forming the lower part of the trunk. It is formed by the two hip bones in front and at the sides, and by the sacrum and coccyx behind. It is a double basin,

the upper part being the wide cavity of the so-called false pelvis, and the lower the smaller, almost circular true pelvis.

The hip bones are two large massive bones, the shape of which may be likened to that of the screw of a ship (Plate III.). The upper part of each hip bone, wide and flattened, is termed the *ilium*, and its upper edge, the iliac crest, can be easily felt; it terminates in front in a well marked thick angle called the iliac spine, which, as it is easily felt, is commonly used as a point from which to make measurements. The lower part of the hip bone, which forms the side of the true pelvis, is an irregular triangle with a large aperture. The two parts of the hip bone are connected by a constricted portion, upon the outer side of which is the acetabulum, the socket for the head of the thigh bone, a deep, cup-shaped cavity, covered for about two thirds of its extent by cartilage. The hinder part of the lower portion of the hip bone is thick and broad; through it the weight of the body is transmitted in the sitting posture; it is called the *ischium* or ischial tuberosity. The anterior portion of the hip bone, termed the *pubis*, articulates, by a disc of fibrous cartilage strengthened by ligaments, with the corresponding part of the opposite side; this joint is known as the symphysis pubis.

In the above description reference has been made to the three parts of the hip bone, the upper part or ilium, the lower and back part or ischium, and the lower and front part or pubis. These three parts are ossified separately, and at birth still consist very largely of cartilage. The ischium and pubis unite by bone about the eighth year, but the acetabulum is not completely ossified until about the eighteenth year. A large epiphysis begins to form along the crest of the ilium at about the fourteenth year, and the hip bone is not completely ossified until the twenty-third or twenty-fourth year.

The sacrum, consisting as already stated of the last five vertebræ fused together, forms the posterior wall of the pelvis, which is continued downwards and slightly forwards by the coccyx.

The Thigh.

The thigh bone or femur is the largest and longest bone in the body, so long that it equals over one fourth of the total height. It consists of an upper extremity, including the head and neck, and two processes called trochanters, a shaft, and a broad lower end

PLATE VI.

Clavicle, Sternum, and Bones of Arm and Forearm, of a Child aged 12 years. (*From a Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

C, Clavicle ; **S.S,** Sternum, shewing six separate parts not yet blended into one bone ; **H,** Humerus, shewing the large epiphysis at the head, and the smaller epiphyses at the lower end ; **U,** Ulna, and **R,** Radius, showing an epiphysis at each end of both bones.

Bones of Shoulder Girdle and Upper Limb.

(Plate VII.). The shaft is nearly cylindrical. Its upper end is slightly flattened before it blends with the two trochanters, great and small, which are buttresses to the neck. The neck, short and cylindrical, is set on the shaft at an angle of 125° and terminates in the head, which forms more than half a sphere and is covered with cartilage. It fits into the acetabulum to form the hip joint. The joint is completed by a strong capsule or capsular ligament attached above to a thick fibro-cartilaginous ring which surrounds the margin of the acetabulum. In the interior of the joint is the round ligament passing from a pit in the head of the femur to the edge of the acetabulum.

The lower end of the femur is broadened out and ends in two rounded eminences, the condyles, united in front but separated behind by the intercondylar notch; the lower surface of the condyles, and the space between them in front, is covered with cartilage, and with the upper part the patella articulates.

The femur is formed from one centre of ossification for the shaft, and by epiphyses, one for the lower end and three for the upper. In the photograph reproduced in Plate VII. the epiphysis for the lower end is well seen; it has just begun to ossify at birth, and does not unite with the shaft until the age of twenty-one years. The epiphysis for the head also is well seen in the Plate VII.; it begins during the first year of life, and unites in the eighteenth or nineteenth year. There is also an epiphysis for the great trochanter, still very small in the photograph, and another for the small trochanter.

The Leg, Ankle and Foot.

The leg contains two long bones: the tibia or shin bone, and the fibula.

The *tibia* (Plate VII.) is, next to the femur, the longest bone in the body; it is the inner of the two bones of the leg, and through it the weight of the body is transmitted to the foot. The shaft has three sides, and its smooth inner surface, for the most part covered only by skin, can easily be felt and is usually called the shin. The upper end of the bone, thick and broad, has two tuberosities, inner and outer. On the upper surface of these are two shallow cavities covered with cartilage, and between them is a rough surface in the centre of which is a spine. Two strong ligaments called crucial,

PLATE VII.

A.—Thigh Bone of a Child aged 9 years. (*Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

The shaft (**S**) has the adult shape, and the neck (**N**) is formed. The epiphysis (**H**) of the head is large, as also that for the lower end (**I**). That for the great trochanter (**T**) is seen to be still very small. The knee-cap (**P**), as yet imperfectly ossified, is seen below the lower end of the thigh bone.

B.—Leg Bones of a Child aged 9 years. (*Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

T, Tibia; **F**, Fibula. The shaft of both bones has the adult shape. The upper and lower epiphyses of both bones are well seen.

A

B

Bones of Thigh and Leg.

Plate VII.

because they cross each other like the letter X, attached to this rough surface and spine, pass upwards and backwards to the sides of the intercondylar notch of the femur. The femur does not rest directly upon the tibia but upon two semilunar cartilages. The knee joint has strong ligaments on either side, and in front is strengthened by the small bone known as the knee-pan or *patella*, which has a joint surface on its posterior aspect, and is attached to the tibia below by the strong ligamentum patellæ. This bone and ligament are easily seen and felt. The lower end of the tibia is much smaller than the upper, and on its inner side there is a thick process forming the inner ankle or internal malleolus.

The *fibula*, a long slender bone, articulates above with the outer tuberosity of the tibia; it ends below in a triangular process which forms the outer ankle or external malleolus.

The tibia and fibula each have one centre of ossification for their shafts, which at birth already consist of bone. The tibia has a large upper epiphysis (see Plate VII.). It is just beginning to ossify at birth, and unites with the shaft at about twenty-one years. The lower epiphysis is also large; it begins to ossify in the second year and joins the shaft at about eighteen. The fibula also, as will be seen in Plate VII., has an upper and lower epiphysis; they do not begin to ossify until the fourth and second year respectively, and are not united to the shaft until the twenty-fourth and the twenty-first year.

The ankle (*tarsus*) consists of seven bones of irregular shape, bound together by strong ligaments. The uppermost bone is the astragalus, which, with the lower ends of the tibia and fibula, forms the ankle joint; below it is the calcaneum or os calcis, projecting backwards to form the heel. The other bones of the ankle are the scaphoid (boat-shaped), cuboid, and three cuniform or wedge-shaped bones. At birth, as may be seen by referring to Plate I., the ankle consists almost entirely of cartilage, centres of ossification being formed only in the astragalus and os calcis. Ossification is going on all through childhood, and is not complete until fourteen or fifteen.

The foot consists of the sole or *metatarsus*, and the toes (*phalanges*). The metatarsal bones, five in number, are small shafted bones which articulate behind with the tarsus, and in front with the first bones of the toes. The inner metatarsal bone

carrying the great toe is stouter and stronger than the others. The great toe, like the thumb, has only two phalangeal bones ; the other toes have three. The shafts of the metatarsal and phalangeal bones are ossified at birth, but the epiphyses, one for each, begin to ossify at various ages from three to eight years, and are not united to the shafts until eighteen or twenty-one.

III.—THE CIRCULATION.

The Blood—The Heart and Pericardium—The Arteries, Capillaries and Veins—The Action of the Heart—The Pulse—Nerves of the Heart—Vaso-Motor Nerves—Influence of Respiration on Circulation—The Lymphatic System—The Lymph—The Lymphatic Glands—The Flow of Lymph.

The blood is constantly in circulation from the heart through the various organs of the body and back again to the heart. The purpose of the circulation is to carry nourishment and oxygen to all the tissues, and to carry away their waste products.

The Blood.

Blood is a slightly viscid fluid, bright scarlet in the systemic arteries (that is, in all the arteries except the pulmonary), dark purple in the veins. It is heavier than water, its specific gravity being 1050, as compared with that of water which is 1000. It is always alkaline, but its alkalinity is greater after meals and least after severe exertion, owing to the acid formed in the muscles during their contraction. It is never acid, so that the popular phrase acidity of the blood is mistaken. It has a salt taste, due to the presence of sodium chloride (common salt), and has a faint characteristic smell. Blood coagulates when drawn; at first it becomes more viscid, then after a few minutes it is a soft jelly. After a time the jelly shrinks, squeezing out an almost clear colourless fluid, and after some hours the much shrunken jelly is floating in a considerable quantity of fluid. The shrunken jelly is the clot, the clear fluid serum.

Chemically the blood consists of eighty per cent. water, and twenty per cent. solids. The solids are chiefly proteids, and the most important is the characteristic body which gives to the red corpuscles their colour. It is called hæmoglobin, and exists in two states: (1) Oxyhæmoglobin, containing an excess of oxygen loosely combined with the proteid, and (2) reduced hæmoglobin, without this extra quantity of oxygen. Under an air pump each hundred parts of blood gives up from fifty to sixty parts of gases, oxygen and

carbon dioxide. Bright red arterial blood contains more oxygen and less carbon dioxide than venous blood, as shown in the following table:

GASSES IN 100 PARTS OF BLOOD.

	Arterial.	Venous.
Oxygen	20 ...	10
Carbon Dioxide ...	40 ...	48

That is to say the tissues have removed from the blood half the oxygen it contained and turned into it a nearly equal quantity of carbon dioxide. In the lungs the process is reversed.

The blood is opaque, even in a thin layer, under the microscope, both its red colour and its opacity being due to the fact that it contains a vast number of red discs. These discs, the red blood corpuscles, are suspended in a clear fluid (plasma); they are bi-concave, that is to say, cupped on both sides, and have no nucleus. If a minute drop of blood be spread out in a thin layer and examined under the microscope, it will be seen that the red corpuscles soon run together and adhere to each other like rolls of coins. Here and there in the clear spaces between the rolls will be seen white or colourless corpuscles, the proportion being one white to five hundred red. They possess a nucleus, and while alive are of various shapes; in fact a white corpuscle possesses the power of spontaneous movement like an amœba, so that its shape is constantly though slowly changing. Several kinds of white corpuscles are distinguished, one of which has the power to take into the substance of its protoplasm any foreign substance, such as a bacterium, with which it comes in contact. White blood corpuscles of this variety are called phagocytes (φαγος, a glutton), and play an important part in the resistance offered by the body to infectious disease.

THE HEART.

The circulation is maintained by the heart, which may be compared to a force pump. The circulation is double, the greater or systemic circulation through the body generally, and the lesser or pulmonary through the lungs. Correspondingly, the heart is a double organ, one side driving the blood into the body generally, the other into the lungs.

The heart is a hollow muscle, having on each side two chambers called the ventricle and the auricle. The auricle is the antechamber of the ventricle; the blood returning to the heart passes through it into the ventricle. It contracts just before the ventricle, into which it forces the blood it contains. The ventricle by its contraction, drives blood into the systemic or pulmonary circulation as the case may be. The muscle fibres of the heart are of a special kind, intermediate between voluntary striped and involuntary unstriped muscle. They are short, nucleated, four-sided cells, with short, thick branches, which join the branches of other cells to form a network. They are finely striped, but have no surrounding membrane (sarcolemma). They are pressed closely together, and gathered into bundles.

The thickness and strength of the walls of the cavities of the heart varies with the amount of work each part has to do. Thus, the walls of the auricles, which merely have to complete the filling of the ventricles, are thinner than those of the ventricles, and the wall of the right ventricle, which has only to send the blood through the lungs, is not so thick as that of the left, which has to drive the blood to every part of the body.

The cavities of the heart are lined by a smooth membrane, the endocardium; this covers the valves also. In certain diseases, and very frequently in acute rheumatism, the endocardium becomes inflamed (endocarditis), and when the valves are involved they first swell and grow rough, and later shrink and crumple so that they obstruct the passage of the blood in the proper direction, and do not prevent its regurgitation in the wrong direction. In consequence, the heart is constantly working at a disadvantage; it has, in fact, more work to do, and like other muscles called upon to do more work, its walls grow thicker and stronger in the attempt to overcome the difficulty it is encountering. This overgrowth or hypertrophy is spoken of as compensating, and as long as the compensation is sufficient, the child may suffer very little inconvenience. But a heart in this condition is easily overstrained, and an amount and degree of physical exercise which would only do a healthy heart good, may produce serious damage to a heart with diseased valves, causing it to dilate.

The general form of the heart (Plates VIII. and IX.) is well

known; it is a short, thick cone, and lies obliquely on the left side of the chest towards the front, with the apex downwards and to the left, and the base upwards and to the right. The heart is about as large as the closed fist, and a general idea of its size and situation may be gathered by placing the left fist on the chest with the wrist on the fifth rib, and the last joint of the thumb on the sternum. On its front surface is a longitudinal groove corresponding to the septum between the two ventricles. The heart is covered by the lungs, or, as it were, embedded in them, except for a small space in front.

The Pericardium.

The heart is contained in a fibrous sac, the pericardium, a serous membrane with the usual two layers, one covering the heart itself, the other the opposite wall of the sac. The inner surface of the pericardium is smooth and glistening, and is moistened by a small quantity of serous fluid, so that when the heart moves, the two surfaces glide upon each other without friction. In inflammation of the pericardium (pericarditis), a common complication of rheumatic fever, the surfaces become roughened, and the friction thus produced by the movements of the heart can be heard and even felt. If the inflammation continues, a large amount of serous fluid may be poured out, distending the pericardial sac and interfering with the action of the heart. After the inflammation has subsided and the fluid, if any, is absorbed, the two layers of the pericardium may become adherent in patches or in all parts, a permanent condition which seriously embarrasses the heart.

The Right Side of the Heart.

The right auricle, an irregular cavity with thin walls, forms the highest part of the heart. It receives the venous blood from the systemic circulation by three veins: (1) the superior vena cava, bringing the blood from the upper part of the body, and opening into it above; (2) the coronary vein, bringing the blood from the heart itself; and (3) the inferior vena cava, bringing the venous blood from the rest of the body, and opening into it below. The orifices of the coronary vein and the inferior vena cava have valves, but neither of them are complete, though they may serve to

direct the stream of blood. The auricle opens into the right ventricle by a large orifice guarded by a valve with three flaps, whence its name, tricuspid valve.

The right ventricle, the front wall of which forms the greater part of the front of the heart, is a triangular cavity, the upper left corner of which is drawn out to open into the pulmonary artery. The muscular bundles, of which the substance of the heart is composed, show on its inner surface, and some of them project as slender pyramids, called the papillary muscles, ending in a bunch of thin tendinous cords inserted into the flaps of the tricuspid valve. The flaps themselves consist of fibrous tissue. When the ventricle contracts, the flaps come together and completely close the orifice into the auricle; they are kept in proper position and prevented from being forced back into the auricle by the papillary muscles and cords.

The opening from the ventricle into the pulmonary artery is guarded by another valve, of very different construction but also possessing three flaps; each flap is half-moon shaped, and the valve is hence called the semi-lunar valve. They are attached all round their convex border to the wall of the artery, where it opens into the ventricle. When the ventricle relaxes after contraction, the pressure of the blood in the artery throws the flaps together and the opening is completely closed.

The Left Side of the Heart.

The left auricle is rather smaller than the right, but has thicker walls. The pulmonary veins, bringing the oxygenated blood from the lungs, open into it, and it communicates with the left ventricle by a wide orifice guarded by a valve with two triangular flaps; when relaxed they resemble a bishop's mitre, and the valve is therefore called the mitral valve.

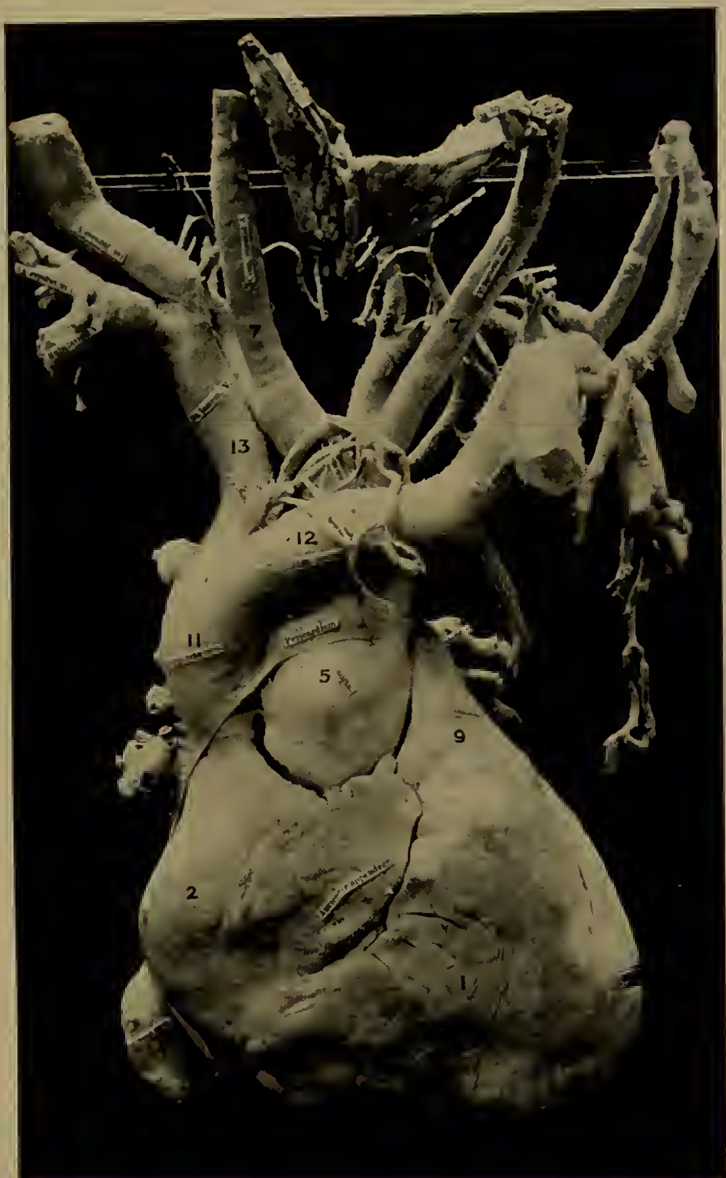
The left ventricle has walls about three times as thick as the right; it lies mainly at the back, but its lowest part forms the actual apex of the heart. The inner surface is marked by muscular bundles similar to those in the right ventricle, and, projecting from the surface, are papillary muscles with tendinous cords attached to the margins of the flaps of the mitral valve, in the same way as in the case of the tricuspid valve. Close to the mitral orifice is the opening into the aorta, guarded by the aortic valve,

PLATE VIII.

HEART AND GREAT BLOOD VESSELS, FROM THE FRONT.

(*Photograph of a specimen of an adult heart Preserved in the Museum of the Royal College of Surgeons of England.*)

1, Right Ventricle; 2, Right Auricle; 5, First part of the Arch of the Aorta; 7, The Common Carotid Arteries; 9, Beginning of the Pulmonary Artery; 11, Superior Vena Cava; 12, Left Innominate Vein; 13, Right Innominate Vein; 14, Inferior Vena Cava.



Heart and Great Blood Vessels (front).

consisting of three semi-lunar flaps of the same form, and acting in the same way as those of the pulmonary artery.

THE ARTERIES.

The arteries are the blood vessels which carry the red oxygenated blood from the left side of the heart to all the organs of the body; they divide again and again, and their final branches end in the capillaries, fine channels forming a network among the cells of the tissues of all the organs. Through their thin permeable walls, the cells extract from the blood the oxygen and the nourishment they require. The veins gather the blood from the capillaries and carry it back to the heart.

The arteries are round tubes composed of muscular and elastic tissue, lined inside by a pavement-epithelium, and strengthened outside by a layer of connective tissue. The muscular fibres are arranged circularly, so that when they contract they narrow the channel of the artery.

Anatomists usually describe three coats: (1) The inner coat, consisting of elastic tissue and the smooth, glossy epithelial lining; (2) the middle, of unstriated muscular fibres covered outside by another layer of elastic tissue; (3) the outer coat of fibrous tissue with some elastic strands. The thickness of the outer coat in proportion to that of the others varies: in the large arteries it is strong and thick, in the smaller it is, in proportion, much thinner. Speaking generally, it may be said that in the smallest arteries the inner coat, in the arteries of intermediate size the muscular middle coat, and in the large arteries the outer fibrous coat, is the most important.

THE CAPILLARIES.

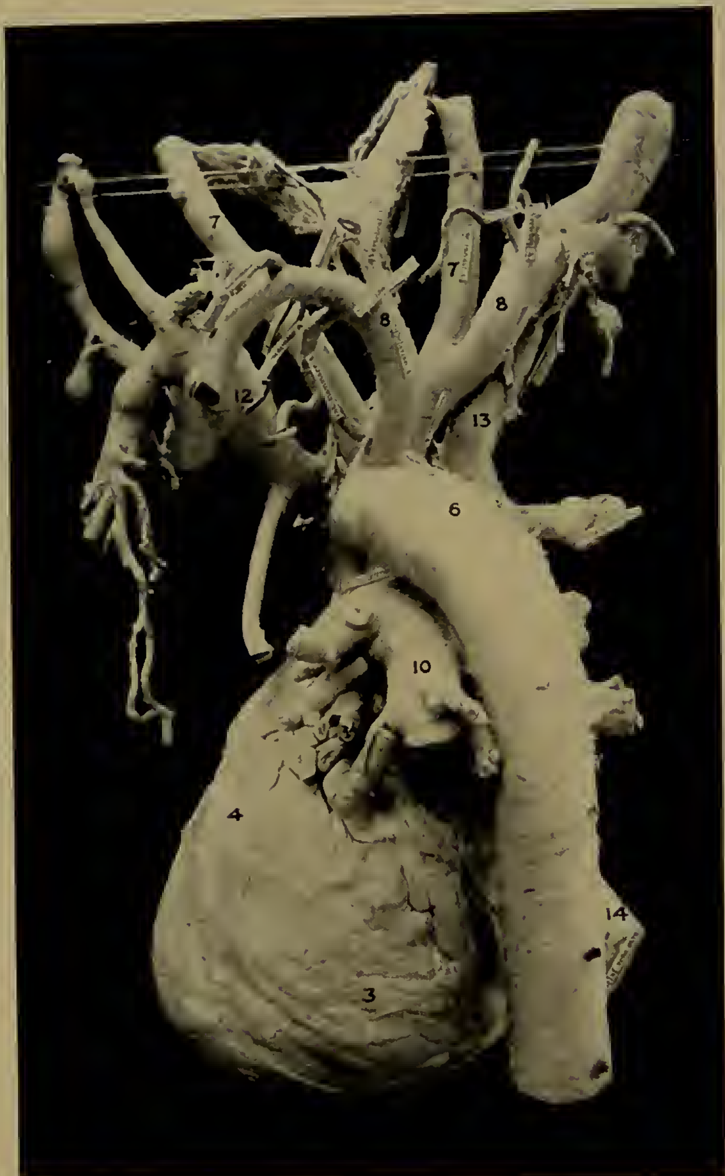
The capillaries are the network of vessels by which the blood traverses the tissues. The shape of the meshes of the network depends upon the arrangement of the cells of the particular tissue; thus among the long fibres of muscle the meshes are long; in the liver they are nearly round, and so on. The capillaries have delicate walls consisting of thin epithelial cells—in fact these vessels may be best regarded as channels, among the cells of a tissue lined by this fine epithelium.

PLATE IX.

HEART AND GREAT BLOOD VESSELS, FROM THE BACK.

(*Photograph of a specimen of an adult heart preserved in the Museum of the Royal College of Surgeons of England.*)

3, Left Ventricle; 4, Left Auricle; 6, Transverse part of the Arch of the Aorta; 7, The Common Carotid Arteries; 8, The Subclavian Arteries; 10, Branches of the Pulmonary Artery; 12, Left Innominate Vein; 13, Right Innominate Vein; 14, Inferior Vena Cava.



Heart and Great Blood Vessels (back).

The Veins.

The veins have thinner and less firm walls than the arteries, so that when empty they collapse, whereas the arteries remain open. Their coats contain less elastic tissue; the middle coat consists mainly of fibrous tissue with only a few muscular fibres, the outer coat is formed of strong fibrous tissue. Many of the veins, especially those of the limbs, have valves, half-moon shaped folds of the inner coat, strengthened by fibrous tissue. The pouches thus formed open in the direction in which the blood flows; if the current of the blood is checked, they fill with blood and flap together, thus preventing the blood from flowing back.

The veins commence by small branches which receive the blood from the capillaries; they unite to form larger and larger veins, and finally end in the upper or lower vena cava, which, as has been said, open into the right auricle of the heart. The upper vena cava collects the blood from the head, neck, spine, upper limbs and upper part of the chest. The rest of the venous blood reaches the heart through the lower vena cava, with the exception of that which comes from the heart itself; this is discharged into the right auricle by a special vein (coronary sinus). The return blood from the digestive organs does not proceed direct to the vena cava and heart, but first traverses the portal system (Fig. 8) as is more fully described in the section on digestion.

The veins of the limbs are divisible into two sets: the deep, which accompany the arteries, and the superficial, which lie immediately under the skin. The veins communicate freely with each other by cross branches, so that if only one or two veins are blocked the blood can find its way onwards by a slightly roundabout route, but if a whole limb is tightly constricted, as for instance when an indiarubber band is put tightly round the arm above the elbow, the veins under the skin will in a minute or so swell up, and can be felt as tense rounded cords, with here and there round knots which mark the places where the valves are. What has happened is this: the band, pressing directly on the superficial veins through the skin, prevents any blood passing on at the place where it is applied, but the artery, having stronger walls and being protected by the muscles among which it lies, remains open, and blood continues

to be pumped through it into the capillaries, flows from them into the veins and distends them. After a time the whole limb below the constriction becomes swollen and of a purplish grey colour from the stagnation of venous blood in it; if the constriction is maintained long enough the limb becomes gangrenous.

If it is wished to arrest the supply of arterial blood to a limb we must proceed in a different way. A point must be chosen where the artery is near the surface and can be compressed against a bone, and the pressure must be made directly on to the artery, so as to arrest all pulsation in it; this can be done with the fingers or with a tourniquet, as explained in books on first aid. The effect is to stop almost completely the circulation in the limb, which becomes pale and cold. It does not arrest the circulation entirely, for the interesting reason that the arteries communicate with each other in a roundabout way by small branches, so that when the chief artery is closed, a little blood finds its way into the limb through these communicating branches; if the artery is ligatured permanently these branches enlarge, and eventually the circulation is restored.

The Arterial System.

The aorta, the great artery into which the left ventricle pumps the oxygenated arterial blood for the supply of the whole body, is shaped like a crooked walking stick. (Plate IX.)

Springing from the top of the left ventricle it first arches over the root of the left lung; this part is called the arch of the aorta. The aorta then descends along the vertebral column through the chest, passes through the diaphragm into the abdomen, and ends opposite the fourth lumbar vertebra, by dividing into the arteries for the two lower limbs (the right and left common iliac arteries).

The first branches of the aorta are the two coronary arteries, supplying blood to the substance of the heart itself; they open immediately above two of the semilunar flaps of the aortic valve. The shortest circuit the blood can take is through the coronary arteries to the capillaries of the heart, and back by the coronary veins to the right auricle. Springing from the top of the arch of the aorta are the large arteries for the head and upper limb. On the left side there are separate branches for the head and the upper limb; the carotid artery for the head, and the subclavian

artery, so called because it passes to the armpit under cover of the clavicle, for the upper limb. On the right side there is one large artery which soon divides into two, carotid and subclavian. The carotid artery runs up the front of the neck on each side and divides into two arteries, the external carotid which supplies the neck, tongue and face, and the internal carotid which supplies the brain and eye. The circulation in the eye is thus really a part of the circulation through the brain, and by examining the inside of the eye with the ophthalmoscope a doctor can learn much as to the state of the circulation in the brain. The brain also receives blood by a branch, the occipital, from the subclavian artery. The four arteries, two internal carotids and two occipitals, after piercing the skull, form a circle at the base of the brain called the circle of Willis. This unusual arrangement is no doubt intended to ensure the regular supply of blood to the brain under all circumstances. The carotid artery is enclosed, along with the internal jugular vein which returns the blood from the brain, in a protecting sheath which also contains the vagus nerve going to the heart and lungs.

The main artery (brachial) of the upper limb runs down the inner side of the arm to the front of the elbow, where it may be felt beating. Here it divides into the ulnar and radial arteries; these run down the inner and outer side of the forearm to the palm. The pulse is usually felt in the radial artery at the wrist, where it lies very near the surface. In the palm each artery branches into two, which curve round and join forming two arches, one deeper than the other. From these arches small arteries are given off to the fingers and thumb.

The descending aorta, as soon as it has passed through the diaphragm, gives off a number of large arteries to the stomach, intestines and kidneys.

The two common iliac arteries, in which, as already said, the aorta ends, themselves divide at the brim of the pelvis; one branch on each side supplies the organs within the pelvis, the other is the great artery of the lower limb. It enters the thigh at the middle of the groin, and may be felt beating two or three inches lower down. It runs as the femoral artery down the front of the thigh, with an inclination inwards to the back of the knee, where it may be felt in

the ham or popliteal space; it is here called the popliteal artery. If one knee be crossed over the other the toe will be seen to move with each beat of the pulse; this is due to the slight compression against the opposite knee-cap of the popliteal artery, which expands with sufficient force to move the whole leg and foot. A little below the knee it divides; one branch runs down under cover of the calf muscles to the back of the ankle at the inner side, where it may be felt beating; it then enters the sole, divides, and forms an arch that gives off twigs to the toes. The other branch passes through to the front of the leg, down which it runs under cover of the muscles to the front of the ankle; from there it is continued to the great toe, giving off branches to the other toes.

Action of the Heart.

In a man the heart beats about seventy times a minute, in a woman about eighty times, in a child more often. The rate, however, varies very much; in some people the heart normally beats faster than in others. At each beat the heart gathers itself together, as it were, the apex tilts forward and the ventricle, suddenly hardening, its front just above the apex, strikes the chest either at or just below the fifth rib on the left side; this is called the impulse or apex-beat of the heart.

The auricles contract first, sending the blood through the tricuspid and mitral valves into the right and left ventricle respectively. The ventricles then at once contract, the tricuspid and mitral valves are closed, the semi-lunar are forced open, and the blood is driven by the right ventricle into the pulmonary artery, and by the left into the aorta. Then immediately ensues a pause during which the ventricles are relaxed, the semi-lunar valves of the pulmonary artery and aorta are closed, the tricuspid and mitral are open, and blood is flowing into the auricles from the great veins, and from the auricles into the ventricles. The contraction is called the systole of the heart, the pause the diastole, from two Greek words, συστολή, contraction, and διαστολή, dilatation. The systole occupies about five-tenths of a second, one-tenth for the contraction of the auricles, and four-tenths for that of the ventricles. The diastole, or resting time of the ventricles, lasts about six-tenths of a second; of the auricles rather longer, since their period of contraction is shorter.

If the time taken by the succeeding systoles and diastoles of the heart be added up it will be found that the human heart, when beating seventy times a minute, works altogether about nine hours and rests about fifteen hours out of the twenty-four.

When the heart beats more rapidly, as during exercise, the systole is a little quicker, but the main difference is that the diastole is shorter. This makes plain one of the dangers of excessive and long-continued muscular exertion: the resting time of the heart is lessened. The heart beats more slowly during sleep. As in children it beats more quickly than in adults, and as, therefore, the pauses during which it rests are shorter in the waking hours, we see one reason why long hours of sleep are required by them. Merely lying down slows the heart, so that even though the child is not asleep rest in bed rests the heart. The frequency of the heart-beats is increased not only by exertion but also by taking food, by alcohol, by some emotions, in fever, and in many conditions of debility. Cold makes the heart work more slowly, heat more rapidly, so that the pulse is a little quicker in a warm than in a cold room.

The time taken by a drop of blood to make a complete circuit of the circulation—right side of heart, lungs, left side of heart, arteries, capillaries, veins, and back again to the right side of the heart—is about as long as the heart takes to beat twenty-eight times. The time taken therefore depends upon the rapidity with which the heart is acting, but it may be said that on the average every drop of blood makes the complete circuit of the circulation at least twice a minute in a man, and probably three times a minute in a child.

The Pulse.

The beat of the heart produces a characteristic sound. It is a double sound, which may be imitated by repeating the syllables lub-dup, and has been compared to the footsteps of a man walking lame. The sounds of the heart, however, can only be realised by listening with the ear to the front of the chest, a very simple observation. The first sound, which is longer than the second, is caused by the sudden closure of the mitral and tricuspid valves, and by the noise produced by the heart muscle in contracting; the second sound, which is short and sharp, is caused by the sudden

closure of the aortic and pulmonary valves. Disease of a valve leads to a change in the character of the sound; if the mitral valve, for instance, is crumpled so that it does not close properly, the first sound is altered; if the aortic, there may be no second sound, but the noise made by the blood rushing back into the ventricle is heard at the beginning of the pause.

At each stroke of the ventricle a certain amount of blood, about three ounces in a man, is driven into the aorta and pulmonary artery respectively. It has to be propelled against the resistance due to friction of the blood against the walls of the smallest arteries and capillaries. The arteries are distensible, that is to say, their walls can be stretched, and elastic, that is to say, the walls when stretched are constantly tending to contract. An indiarubber band lying on the table is distensible, it can be stretched. As soon as it is stretched it is elastic, and is therefore constantly tending to contract to the size and shape it has when not stretched. The arteries are always on the stretch, for the heart keeps them a little over full, and they, being elastic tubes, keep up a constant pressure on the blood, squeezing it into the capillaries.

The sudden addition to the contents of the already slightly distended arterial system, of the amount of blood expelled by the contraction of the left ventricle, produces a wave throughout all the arteries of the body called the arterial pulse, or shortly, the pulse. It may be felt in any accessible artery, the most accessible being the radial near the wrist, or the temporal on the temple. The pulse being directly due to the heart's action is, of course, quickened or slowed by the same causes as affect the rapidity of the heart.

The Circulation and the Nervous System.

Nerves of the Heart.

The nervous mechanism of the heart is complex, and not fully understood. The actual contractions are brought about by the substance of the heart itself, which contains many nerve-ganglia, but their rate and force are controlled by two sets of nerves derived from the medulla oblongata and the spinal cord. The one set, which reaches the heart through the vagus nerves, restrains; the

other, which passes through the sympathetic nervous system, stimulates its activity. The rate and force of the heart are beyond the control of the will, but may be affected by emotion.

Vaso-Motor Nerves.

The arteries are supplied with nerves called vaso-motor, because they regulate the calibre of the vessels by stimulating the muscular fibres in their walls. They are all connected with a centre in the medulla oblongata: when this centre is stimulated, the arteries contract. It is stimulated in two ways (1) directly by a venous state of the blood circulating in the centre itself or by emotions, and (2) reflexly by impressions received by the centre through the sensory nerves of the skin and other organs. The constriction of all the arteries due to stimulation of the centre, causes an increase of blood pressure, and this increase causes the veins and right side of the heart to become distended; the heart receives more blood, and in consequence acts more rapidly. In this way the whole circulation is quickened. There are other nerves which when stimulated produce the opposite effect, that is to say, dilatation of the vessels. The veins also are controlled by vaso-motor nerves.

The size of the vessels in a part can be affected by local applications. For instance, cold applied to any part of the skin causes constriction of the vessels and the part becomes white; heat has the opposite effect, producing dilatation of the vessels and redness and heat of the skin. Strong mechanical irritation of the skin and electrical stimulation have the same effect.

Normally the vaso-motor centre is constantly in action, producing slight constriction of the arteries. This condition is called arterial tone; a normal tone has a great deal to do with the sense of well-being felt in health, when neither too cold nor too hot. The tone may be disturbed locally or generally in many ways. At the beginning of an attack of fever there is usually general constriction, causing a sensation of chill or actual shivering. This is a fact which should be borne in mind by teachers; a child who looks pale, feels cold, and perhaps shivers a little without obvious cause may be sickening with some infectious disease. Usually the temperature of the body is already raised at this stage. This

coldness of the surface is followed by the opposite condition, dilatation of the vessels leading to the heat and redness of the skin commonly associated with the idea of fever. Local inflammation produces the same sequence of events in the part affected; for instance, the first symptom of a cold in the head is a disagreeable dryness of the nostrils, followed by swelling of the mucous membrane, and eventually by a watery discharge. The constriction of vessels and pallor of the skin which follows a blow is very brief and is almost immediately succeeded by dilatation of the vessels and redness of the skin. Blushing of the face is an example of local dilatation produced by emotion; the pallor caused by fright of the opposite effect, constriction.

Influence of Respiration on Circulation.

The lungs are elastic, and if the chest be cut open they shrink. Normally, owing to this elasticity, they are constantly tending to shrink, but as they cannot do so they exert a pull on the chest walls, and on every organ in the chest. Among other organs they pull upon the heart, and have a considerable suction action on the auricles and great veins. This suction action, as will be readily understood, is greater in inspiration when the chest is expanding, and less in expiration. The expanding chest in inspiration has a pump-action on the right auricle and great veins, tending to draw the blood into them; during expiration, when the suction action is much diminished, the blood is prevented from flowing back through the veins by their valves, so that the current in them, though it may be momentarily checked, is never reversed. Further, a deep inspiration has a greater suction effect than a shallow, and the more frequently inspiration is repeated, the greater must be the total effect on the blood in the great veins and the right auricle; now, as more blood reaches the right ventricle, more blood traverses the lungs, and ultimately reaches the left ventricle, and, as more blood reaches both sides of the heart, the heart must contract more vigorously and frequently. This is one way, a mechanica way, in which exercise favours the circulation, quickening and strengthening the heart, and hastening the flow of the venous blood. Respiration also affects the circulation, through the nervous system, in two ways. Firstly, inspiration acting through the vagus nerve

quickens the action of the heart, and the more frequent the inspiration the greater the total effect. Secondly, a deficiency of oxygen in the blood circulating in the vaso-motor centre in the brain, stimulates it and leads to a rise of blood pressure, which, as has been said, quickens the circulation.

The Lymphatic System.

Every organ and tissue of the body contains lymphatic vessels, thinner and more delicate than the veins, but like them provided with valves. The lymphatics assist in distributing to the tissues nutriment which they derive from the blood. They play an important part in the absorption of certain of the products of digestion from the intestines and their conveyance into the blood, but in other organs their chief use is to supplement the work of the veins in removing waste products. The current of lymph in the lymphatic system flows only in one direction, that is from the tissues.

The Lymph.

The lymph is a clear, colourless alkaline fluid, containing albumen in solution and lymph cells. When withdrawn from the body, a scanty, soft gelatinous clot forms in it. The lymph in the lymphatic vessels of the intestine (lacteals) is milky during digestion from the presence of fat globules, and is called chyle.

The lymph first collects in the fine spaces between the actual cells of a tissue; these open into larger channels called lymph capillaries, which again open into the lymph vessels. In the brain, the liver and in bone, the smallest blood vessels are completely surrounded by lymph vessels, within which they lie like a finger in a glove. The lymphatics also communicate directly with serous cavities by small openings through the epithelium of the serous membrane.

The lymph cells are derived chiefly from the lymphoid tissue, others enter the lymphatics from the spleen and bone marrow where, as well as in the lymphatic glands, they are formed. Some are derived from the tissue cells and a few from the blood, some of the leucocytes wandering out of the capillaries into the lymph spaces.

The Lymphatic Glands.

Lymphoid tissue exists in most organs. It consists of a delicate network of connective tissue containing lymph and lymph cells, is surrounded by blood capillaries, and drains into lymph capillaries. In some situations, as in the intestines, it is collected into small spherical masses about the size of a pin's head (lymph glands, Peyer's patches).

Fig. 2.—Diagram of the Structure of a Portion of a Lymphatic Gland.

A, afferent lymph vessels carrying lymph to the gland; E, efferent lymph vessels carrying lymph away; B, small blood-vessel making capillary loops; C, capsule; L, lymphoid tissue surrounding the blood capillaries; T, fibrous supporting bands. The lymph finds its way through the loose tissue between the lymphoid tissue and the fibrous bands.

In the course of the lymphatic vessels in certain situations occur the lymphatic glands, large collections of lymphoid tissue arranged in a special way. A lymphatic gland has a thin, fibrous capsule,

containing unstriped muscular fibres. Bands of fibrous tissue starting from the capsule traverse the gland in all directions, forming many communicating cavities. Blood vessels enter the gland and form long loops in the cavities; the loops are sheathed in lymphoid tissue, and the space between this and the wall of the cavity is the pathway of the lymph (Fig. 2).

Lymph vessels from the tissues (afferent) enter the glands on one side and open into the cavities. The lymph passes slowly through the gland and is collected on the other side by other lymphatic vessels (efferent).

The lymphatic glands are numerous in some situations; there are collections in the front of the neck under the sterno-mastoid muscle, at the back of the neck, in the armpit and in the groin. There are numerous lymphatic glands also in the mesentery which receive the lacteals, and several at the root of each lung.

The lymphatic vessels and glands play an important part in local inflammation. An infected wound of the finger may be taken as an example: if the wound is not properly treated, the lymphatic vessels become inflamed and show as red lines in the skin; the glands become swollen and tender, first one at the inner side of the elbow, and then those in the armpit. If the infection is less acute, the vessels may not be obviously inflamed, and the only thing to be noticed is the swelling and tenderness of the glands; they appear to be attempting to arrest the infection, and probably succeed in many instances. A tender lump at the elbow or in the armpit should immediately raise suspicion that there may be a poisoned wound on the hand, wrist or arm; prompt treatment may be expected to cause the inflammation to subside, and so prevent abscess in the armpit, or even fatal blood poisoning. Chronic inflammation of an organ causes painless enlargement of the glands to which its lymphatics go. This is often seen in the neck, where it is commonly due to a chronic form of tuberculosis, formerly called scrofula. The tubercle bacilli find entrance by way of the throat, particularly through the tonsils; they are carried by the lymph stream to the nearest glands, those in the neck, where they are arrested. In a healthy, vigorous child, the bacilli are destroyed by the cells of the gland, but if there is a predisposition

to consumption, or if the way has been paved for them by repeated sore throats, attended by temporary enlargement of the glands, then they become established. They grow and multiply, causing a chronic inflammatory hardening and enlargement. If this is neglected, the gland softens after a time, the skin becomes inflamed, and an opening forms through which the broken-down substance of the gland discharges, leaving eventually an unsightly scar. In consumption the lymphatic glands at the root of the lungs become inflamed, as do the glands in the mesentery when tubercle bacilli are present in large numbers in the intestines. Milk from tuberculous cows can set up tuberculosis in this way.

The Flow of the Lymph.

The lymph, after flowing through a gland, often through several glands in succession, is collected by larger lymphatic vessels, which converge from all parts to the two lymphatic ducts. These two ducts, called the right lymphatic duct and the thoracic duct, open into the venous system at the point where the subclavian unites with the internal jugular vein. The openings are each guarded by a double valve which allows the contents of the duct to pass freely into the vein, but effectually prevents reflux. The *right lymphatic duct* receives the lymph from the right side of the head and neck, the right upper limb, and the upper part of the trunk on the right side. The *thoracic duct* receives the lymph from all other parts of the body, including the digestive organs. It begins a little above the brim of the pelvis, and runs up in contact with the bodies of the vertebræ as high as the fourth dorsal vertebra, where it curves to the left and enters the vein. It is a long, irregular tube, with a dilatation at the level of the first lumbar vertebra, called the receptacle of the chyle, into which the lymphatics of the intestine (lacteals) open.

The flow of the lymph is much slower than that of the blood, and is maintained in one direction by the existence of numerous valves in the lymphatics which prevent back flow, so that any pressure on a lymphatic vessel must force the lymph onwards. In man, the flow is chiefly due to indirect causes: (1) the lymph is secreted in the tissues under a certain low pressure, due to the blood pressure; (2) every dilatation of the blood vessels exerts a

certain pressure on the lymph vessels, and this is especially marked in the lymphatics which surround blood vessels ; (3) every muscular contraction squeezes the lymphatics in or near the muscle, and drives the lymph on ; (4) lymph is sucked into the open pores of the pleura with each inspiration ; (5) the muscular fibres in the capsule of the glands help by their contraction to drive the lymph out of the glands. If the flow of lymph is arrested, dropsy or œdema is produced ; dropsy means accumulation of fluid in a serous cavity, œdema in a tissue.

IV.—RESPIRATION AND AIR.

The Respiratory System—The Nose—The Larynx—The Lungs—The Thorax—Inspiration and Expiration—The Nervous Control of Respiration—Air—Impurities of Air—Ventilation—Ventilation of School-Rooms.

RESPIRATORY SYSTEM.

The respiratory system consists of the lungs and chest, and of the upper air passages—nose, pharynx, larynx and trachea.

The lungs and chest act as a bellows; when the chest expands it draws air into the lungs through the upper air passages, when it shrinks again the breath is expelled by the same route.

The *nose* is divided into two cavities by the central septum, which is cartilaginous in front and bony behind. The internal surface is lined by mucous membrane containing many blood vessels and mucous glands. In tranquil breathing the air passes along the floor and middle level of the nose, hence called the respiratory part; its epithelium is ciliated, and the cilia sweeping constantly outwards keeps the mucous membrane clean. The air passes out of the nose through the posterior nares into the pharynx, a short, funnel-shaped tube with thin, muscular walls lined by mucous membrane, common to the functions of respiration and deglutition; it is attached above to the base of the skull and ends in the œsophagus. Into the front of the pharynx are three openings: the uppermost is the double opening into the back of the nose (posterior nares); below this is the opening into the mouth (fauces); and below this again is the upper aperture of the larynx. It is in the part behind the nose, called the naso-pharynx, that adenoid vegetations form.

The *larynx* is the organ of voice, and consists of a framework of cartilages connected by elastic ligaments. In its general form it is funnel-shaped, its lower, narrow end opening into the trachea or windpipe. The upper orifice of the larynx is guarded by the epiglottis, a thin sheet of cartilage shaped like the leaf of a plantain.

In swallowing it is pulled down by muscular action over the aperture of the larynx and thus guards against the entrance of food into the air passages. Occasionally, as when a crumb goes the wrong way, or when a coin or button is "swallowed," the vigilance of the epiglottis is evaded, and the foreign body entering the larynx causes a severe fit of coughing and much distress. In the interior of the larynx are two pairs of projecting folds: the upper or false vocal cords formed of mucous membrane and not concerned in the production of the voice, and the lower, or true vocal cords, by the vibration of which the voice is produced. These cords have a thin edge like the blade of a knife. The larynx is a reed instrument, and the various notes and tones are due to variations in the tension of the cords and the space between them. Each cord is fixed in front to the angle of the thyroid cartilage (Adam's apple), but behind it is attached to a small, freely movable triangular cartilage (arytenoid). The tension and position of the cords are regulated by small muscles attached to this cartilage. The whole larynx is lined by a delicate mucous membrane; inflammation of this membrane, especially if it spreads to the muscles, causes hoarseness. Improper or excessive use of the voice results in thickening of the vocal cords, with the result that the tone of the voice is damaged. In childhood the larynx is small, light and rounded; as the girl grows to womanhood the cartilages of the larynx grow stronger but do not change much in form, so that she retains a high pitched voice. In the boy important changes in form occur; not only do the cartilages become much larger and stronger, but the angle of the thyroid projects forward in Adam's apple, and the length of the vocal cords increases. It is this increase in the size of the larynx, and in the length of the cords, which produces the deeper voice of the man. These changes, commonly known as the breaking of the voice, occur at from fourteen to sixteen years of age.

The *trachea* or windpipe is a tube about four and a half inches long, held open by a series of firm, cartilagenous C shaped rings. The back part is membranous, and the whole is supported in place by loose, connective tissue. It is lined by ciliated mucous membrane, the cilia being constantly in motion, sweeping upwards any solid particles which fall upon it. It ends below in the two main bronchi going to the right and left lung respectively. They have the

same structure as the trachea on a smaller scale. They are short, wide tubes, the left being rather longer than the right; each passes to the root of the lung and there divides into many branches which penetrate the substance of the lung.

The Lungs.

The general plan of the structure of the *lungs* may be compared to a short tree with many branches. The system of bronchi is indeed sometimes called the bronchial tree; the main bronchus represents the trunk of the tree, the smaller bronchi the branches, and the air cells the foliage.

Each lung is in form an irregular cone with the apex upwards; the outer convex surface is in contact with the chest wall, the base, which is slightly concave, with the diaphragm, while the inner side is hollowed out to make room for the heart and great blood vessels. The lung is thin in front where it overlaps the heart; it is thick behind where it fits into the posterior curve of the ribs and extends much lower than in front. It should always be remembered that, owing to these anatomical peculiarities, the great bulk of the lungs lie behind. The right lung, the larger of the two, is divided into three unequal portions called lobes, upper, lower and middle; the left, considerably smaller on account of the position of the heart on that side, has only two lobes, upper and lower. A healthy lung is of spongy consistency, and, owing to the large amount of air it contains, will float in water when removed from the body. The outer surface of the lungs and the inner side of the chest wall are covered by the serous membrane called the pleura. The space between the two layers is called the pleural cavity, but it must be understood that in health there is really no cavity, the two surfaces being kept in close contact by atmospheric pressure, and merely lubricated by the serous fluid. In pleurisy there may be rapid secretion of fluid into the pleural cavity, the lung shrinking to make room for it.

The finest bronchial tubes finally end in a cluster of short, dilated branches, arranged much as a bunch of grapes tightly packed round the stalk; each dilatation (infundibulum) is folded inwards upon itself, making a large number of small cavities called the *air-cells*. They are lined by a delicate epithelium, consisting

mainly of large thin cells. There are also a certain number of rounded amœboid cells, which take up inhaled particles of, for instance, soot or coal dust; these cells migrate into the substance of the lung, where the carbonaceous particles being indestructible remain permanently. When this process has been going on for many years, the lung, normally light pink, becomes slate coloured or even black. The large blood vessels of the lung enter it at the root, along with the main bronchus; the pulmonary artery carries the blood from the heart to be purified in the lungs, and the pulmonary vein brings the blood back to the heart again. In the walls of the air-cells there is a capillary network, and it is here that the blood is purified of the excess of carbon dioxide, and takes up the oxygen from the air in the air-cells.

Respiration.

The chest (thorax) is the bony and muscular cage containing the lungs and the heart with its great vessels. Its walls are formed by the ribs and the intercostal muscles (*inter*, between, and *costa*, a rib), which fill the spaces between the ribs; they articulate with the spinal column behind and the sternum in front. The chest is closed below by the diaphragm, which separates it from the abdominal cavity. The diaphragm is a thin muscle with a flat tendon in the centre; its muscular fibres are attached all round to the ribs, to the sternum, to some of the costal cartilages in front, and by two strong muscular bands called the pillars of the diaphragm, to the bodies of the vertebræ. At rest it forms two domes, one on either side, rising into the chest: when it contracts in inspiration, the whole muscle is pulled down and flattened, the domes disappearing, so that the depth of the chest downwards is increased. At the same time the muscles attached to the ribs, which it will be remembered slope downwards, pull them up, and in this way the diameter of the chest from back to front is increased.

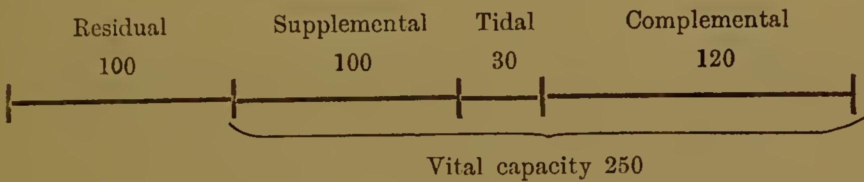
Each respiration consists of two distinct acts: inspiration, or the drawing of the air into the lungs, and expiration, or its expulsion. After each expiration there is a short pause; the respiratory muscles must work night and day, waking or sleeping, and it is during these short pauses that they rest. In health the respiratory act is repeated fourteen or sixteen times a minute in adults,

and rather more often in children. In quiet breathing, muscular action is necessary for the act of inspiration only, expiration being brought about by the elasticity of the thorax and the relaxation of the diaphragm. In ordinary inspiration, the first and second ribs are fixed by the scalene muscles, which pass to them from the vertebræ of the neck; the remaining ribs are pulled up by the external intercostal muscles and the elevators of the ribs, which pass from the spine downwards and forwards. These muscles, with the diaphragm, are called the ordinary muscles of respiration. In rapid, forced breathing, caused by exertion or diseases of the lungs such as pneumonia, other muscles come into action. The muscles of the shoulder girdle fix the upper part of the chest, and the impulse of a person very much out of breath is to clutch at some fixed point above his head, such as the top of a gate, so as to raise and fix the upper part of the chest. The great pectoral muscles, attached to the shoulder girdle and spread out over the chest in front, thus obtain a strong purchase on the upper ribs. Other muscles which can raise the ribs, as, for instance, the serratus magnus, are also brought into action. In forced breathing, expiration also is completed by muscular action, abdominal muscles in particular coming into play to pull down the chest. These are known as the extraordinary muscles of respiration.

A cough is a forcible expiration produced by the irritation of mucus or a foreign body in the air passage; the glottis at the beginning of the act is closed, and is, as it were, burst open by the sudden blast of air expelling the irritant. Sneezing is a similar movement, but the blast is directed through the nose. In tranquil respiration, a certain amount of air, about thirty cubic inches, nearly a pint, is inspired and expired; this is called the tidal air.

By a forcible expiration after an ordinary inspiration about 100 cubic inches more air can be expelled; this is called the supplemental air. But the lungs are not emptied by the most forcible expiration, and the air that remains, about 100 cubic inches, is called the residual air. The amount of air that can be taken in by the deepest inspiration, over and above the tidal air, is about 120 cubic inches and is called the complemental air.

The total quantity of air that can be expired by a forced expiration after a forced inspiration, is termed the vital capacity of the lungs. It varies in different persons, but the average for a man is about 250 cubic inches.



The tidal air of ordinary respiration does not enter deeply into the lungs, probably not much beyond the larger bronchi. The oxygen of the air in the deeper parts is renewed by diffusion. The chief change which occurs in the air during the process of respiration is that five volumes per cent. of oxygen are absorbed and replaced by four volumes of carbon dioxide. Moreover, the expired air is raised to the temperature of the body, and is saturated with moisture. The oxygen absorbed in the lungs is carried by the blood to all the organs of the body, and is used up in the chemical changes necessary to life which take place in the food stuffs and in the tissues. These changes are of the nature of combustion or oxidations, that is to say, a combination of oxygen with the carbon, hydrogen and nitrogen of the complex bodies that make up the tissues. By oxidation they are converted into simpler and still simpler bodies; the final products in the case of carbon and hydrogen being carbon dioxide (CO_2) and water (H_2O). Most of the used up nitrogen leaves the body as urea, as is more fully explained elsewhere.

The movements of respiration are involuntary, and continue during sleep and unconsciousness, although they can be checked or increased for short periods by an effort of the will; the increased movements accompanying exertion are also involuntary. The regulation of the rate and depth of breathing is dependent on the central nervous system, and there is a small area in the lower brain or medulla oblongata, the central point of the whole nervous mechanism of respiration; it is therefore called the respiratory centre or *nœud vital*, because its destruction arrests breathing and rapidly produces death.

The respiratory centre is itself very sensitive to changes in the proportion of oxygen in the blood which reaches it. It receives also afferent impulses from the sympathetic system through the great pneumo-gastric or vagus nerves, branches of which are distributed to the air-cells. The efferent or motor nerves arise from the spinal cord; they are (*a*) the two phrenic nerves, which run from the cervical part of the spinal cord through the neck and chest to the two sides of the diaphragm, and (*b*) the intercostal nerves, which arise from the dorsal part of the cord and run between the ribs to supply the intercostal muscles. The quickening of breathing accompanying exercise is familiar to everyone. It is due to the fact that during muscular exertion more oxygen is consumed by the tissues and more carbon dioxide produced; the increased amount of the latter in the blood stimulates the respiratory centre, and this immediately responds by increasing the rapidity and depth of the respiratory movements. In this way more air is taken into the lungs, more oxygen absorbed and more carbon dioxide exhaled. At the same time the circulation is quickened, so that the blood carries oxygen to the tissues and removes the carbon dioxide from them more rapidly. The greater the exertion, the greater the amount of carbon dioxide produced and the more rapid and violent the respiratory movements. The respiratory centre responds in exactly the same way to the presence of an excess of carbon dioxide in the blood from any other cause: for instance in suffocation. The movements of respiration become more and more violent, until general convulsions ensue; before this, however, the vitiated blood acting upon the brain has rendered the individual unconscious.

To summarise then, it may be said that the whole object of respiration is to maintain the oxygenation of the blood. The chest, by its bellows action, draws air into the lungs; the oxygen, diffused into the air-cells is taken into the blood and carried by it to the tissues, there to be used up in the oxidation processes by which energy is developed. The resulting carbon dioxide taken into the veins is carried back to the lungs and exhaled.

AIR.

Air is a mechanical mixture of gases, chiefly nitrogen and oxygen, with small quantities of argon and carbon dioxide,

commonly called carbonic acid gas. The composition of pure dry air is as follows:

Composition of air (by volume) in 10,000 parts.

Nitrogen	7802
Argon	100
Oxygen	2094
Carbon dioxide	4
	10,000

Nitrogen, which forms about four fifths of the atmosphere, is a necessary constituent of the tissues of animals and plants, so that life is impossible without it, but in the air it merely dilutes the oxygen. It is an inert gas, having neither taste nor smell, and cannot support combustion or life. *Argon*, recently discovered by Lord Rayleigh and Sir William Ramsay, resembles nitrogen but is still more inert.

Oxygen, which forms about one fifth of the air, is an odourless, tasteless gas: it is necessary for combustion, and for nearly all forms of life. An animal deprived of oxygen quickly dies of suffocation. Fresh air contains traces of a special form of oxygen called ozone, in which three parts of oxygen are condensed into the space normally occupied by two; it has a peculiar pungent odour when present in large quantities, such as are produced by a powerful electric machine. The proportion of ozone in the atmosphere varies very much according to locality; it is generally absent in dirty or crowded places, usually plentiful in fresh country air, and most plentiful at the sea.

Carbon dioxide is a colourless gas produced by every form of combustion, by the breathing of men and animals, and by the processes of decay and putrefaction. It is the gas most often present in effervescing mineral waters, and is discharged from volcanos. The proportion present in the atmosphere varies considerably, and, speaking generally, it is greater in crowded towns than in the country. In pure mountain or sea air there may be as little as 2·5 in 10,000 parts; in towns there is seldom less than 4; when the air is still, the area crowded, and many fires and furnaces

burning, the proportion becomes much higher. In ill-ventilated rooms, workshops, cowsheds and stables, a very large proportion may accumulate. A normal proportion of carbon dioxide, which may be taken to be about 4 per 10,000, produces no injurious effect, but if the quantity is much greater, headache, nausea and a general feeling of discomfort comes on. Fidgeting, yawning, wandering of the attention, and general slackness in school may often be accounted for by the accumulation of an excess of carbon dioxide in the air of the school-room.

Air always contains a certain amount of invisible watery vapour, the higher the temperature the greater the quantity. When air contains the full amount of watery vapour possible at a given temperature, it is said to be saturated; if the highest amount is taken to be 100 parts, and the air at a particular time contains only 75 parts, it is said to have 75 degrees of humidity. A fall of temperature causes the invisible watery vapour to condense as fog or cloud, consisting of globules of water so minute that they float in the air. A familiar example is the visible cloud, produced on a frosty morning by the breath saturated with moisture as it leaves the lungs. The mists which rise over rivers, lakes and marshes are produced in a similar way. During the day the water, warmed by the sun, is continually rising in invisible vapour; when the temperature of the air falls at sundown, or when a current of cold air flows over the water, the vapour in the air is condensed. The yellow fogs of London and some other large cities are produced by the coating of each watery globule with a layer of greasy soot from coal smoke. Such fogs do not exist in towns where wood or coke is burnt, and would disappear from this country if gas was more generally used for cooking and heating.

Air, as a rule, contains from 50 to 70 degrees of humidity; if the proportion is much above this the air feels moist and oppressive; if much below, unpleasantly dry. Moist air reduces the evaporation from the skin, while dry air withdraws both water and heat. Air contracts with cold and expands with heat, so that a cubic foot of air becomes much lighter when its temperature is raised from freezing point to, say, 60° F. Watery vapour is lighter than air, so that moist air is lighter than dry. Variations in the density of the air produce a rise and fall of the barometer.

Diffusibility is an important property of gases: it is due to the fact that the molecules of a gas are in rapid motion. Of the gases of the atmosphere, carbon dioxide is heavier than oxygen, and oxygen than nitrogen, but they do not separate into layers, because it is the nature of a gas spontaneously to mix with, or diffuse into, any other gas with which it comes in contact. Consequently the carbon dioxide produced by respiration and fires disperses rapidly, a process which is assisted by the circulation of the air due to winds. Owing to these two causes, the proportion of carbon dioxide in the open air is kept at or near the normal standard.

Impurities of Air.

Impurities of the air are gaseous or solid. They are produced by (1) fires, especially coal fires, manufactories and traffic; or (2) by emanations from animals or from decomposing animal or vegetable matter.

Gaseous Impurities.

The gaseous impurities are compounds of nitrogen, sulphur or carbon.

Nitrogen Compounds.

Ammonia, derived in the main from decaying animal and vegetable matter, is to be detected in minute quantities in the air of nearly all places.

Nitric and *nitrous acids* arise from the same sources, but are produced also by electric storms, and by certain manufactories.

These nitrogen compounds are irritating, but, except under rare circumstances, the amount in the air is so small that they are not perceived, and produce no inconvenience; when a large proportion is present, the respiratory system is irritated and bronchitis may ensue.

Sulphur Compounds.

Sulphurous acid is produced by combustion, especially of coal, and is consequently almost always present in the air of towns; it is injurious to vegetable life, and the chief cause of the difficulty in growing flowers and trees in towns; it also eats away metals, and injures pictures. It causes irritation of the lungs and bronchitis.

Sulphuretted hydrogen, which has the offensive odour of rotten eggs, is produced not only by combustion under certain conditions, (gas works, chemical works), but also by foul drains and marshes. It is very poisonous, but so offensive that it is seldom a source of danger, though when present in even small proportion it may cause nausea and diarrhœa. It tarnishes metal, and spoils the colour of pictures.

Carbon Compounds.

Carbon dioxide, or carbonic acid gas, has already been mentioned as a constant constituent of air.

Carbon monoxide is far more poisonous than carbon dioxide. It is due to imperfect combustion, and is produced in large quantities when charcoal or coke is burnt in a brazier or open grate, or in a cast-iron stove. Ordinary coal-gas contains seven or eight per cent., and even more when it is partly composed of so-called water-gas. When breathed, it enters into combination with the hæmoglobin of the red blood corpuscles, displacing the oxygen, and is only got rid of very slowly. It thus acts as a poison by stopping the respiratory exchange in the lungs and arresting the oxidation of the tissues. A small leakage of gas may lead to the accumulation of a proportion of carbon monoxide in the air of a room sufficient to cause dizziness, headache, flushing of the face, constriction about the temples, and some confusion of mind.

Carburetted hydrogen is another product of combustion of coal; it is usually found in very small quantities, and is comparatively harmless. It is frequently present in large proportions in coal mines, and is one of the chief constituents of illuminating gas.

Sewer gas, which contains sulphuretted hydrogen and other impurities, has been known to cause vomiting and diarrhœa, and, by the depression of health it produces, predisposes to sore throat, erysipelas and child-bed fever.

Solid Impurities.

The nature and amount of the suspended matters in air vary very greatly with the locality and the state of the weather. Rain carries down with it much suspended matter, and, as it were, washes the air; electrical discharges (lightning) also cause particles floating in the air to fall. A moderate breeze carries away

impurities from a town, while a gale, or gusts of wind without rain, raise dust from streets, roads and fields.

The fine floating particles, spoken of as dust, are a very heterogenous collection of granite and wood from the pavement, and every kind of vegetable and animal matter with which the streets are fouled, ground fine by the traffic. Coal dust, iron rust, fine hairs, or fragments of wool, silk, cotton and flax, and epithelial scales from men and animals may form part of the dust of a town; it is in fact dried mud in powder. In addition, bacteria are present, though seldom or never in large numbers in the open air.

The inorganic parts of dust, such as sand, do not, under ordinary conditions, cause anything more than inconvenience, but in certain trades the fine mineral dust suspended in the air irritates the respiratory system, and leads to lung disease. Miners suffer in this way from the fine dust in coal and tin mines; knife, needle and file grinders from the metallic dust in the grinding rooms; potters from the fine clay dust which rises in the pottery sheds, and so on with other dusty trades. The irritation set up by dust often paves the way for consumption of the lungs. Lead poisoning, producing colic, paralysis, fits, occurs among workers in white lead factories owing to inhalation of the finely ground white lead.

The organic parts of dust, such as fibres of silk, cotton, etc., produce irritation of the respiratory system in the same way as the inorganic; lung diseases are therefore prevalent among cotton, silk, wool and flax workers.

Certain infectious diseases are spread through the air—tuberculosis, scarlet fever, influenza and small-pox—but how far the bacilli commonly present in the open air are ever injurious to health is not very certain; it is probable that the infection of summer diarrhœa is sometimes spread in this way among children. Work people who handle hides and fleeces from animals which have died of anthrax, a disease due to a bacillus, may contract it by inhalation (wool-sorters' disease).

Consumption of the lungs (phthisis, pulmonary tuberculosis) is due to infection by the tubercle bacillus discovered by Koch in 1881. It is present in enormous numbers in the expectoration of persons suffering from the disease. If this infected expectoration falls on floors, carpets or clothes and dries, it is reduced to dust,

is swept into the air and breathed into the lungs. A healthy person with healthy lungs is able to resist the infection, and the bacilli are digested and destroyed by the cells of the lungs and other organs. If the epithelial cells of the lungs are damaged by constant inhalation of irritating dust, the tubercle bacilli readily obtain a foothold, and if the general health is at the same time depressed by long hours of work in crowded, ill-ventilated factories, work-rooms or schools, the risk of contracting the disease is increased, and the constitution is less capable of resisting it.

VENTILATION.

When we remember that the air of a room is constantly being vitiated by the respiration of the persons living in it, by the products of the candles, oil or gas used for lighting, and by the dust apt to be raised by every movement, it is easy to see that there is a constant need for bringing in pure air and expelling or extracting the vitiated air.

The art of ventilation consists in doing this efficiently, without producing draughts and without making the air of the room unpleasantly cold, a task theoretically easy but practically, in a variable climate, very difficult, especially in buildings such as schools, where many people are brought together in a small space. The subject is well worth careful study, for it is impossible for either the body or the mind to work well in a vitiated atmosphere. A person who habitually lives in such an atmosphere grows anæmic, suffers from fatigue, loses appetite, and becomes very susceptible to many diseases, including consumption.

Systems of ventilation are natural or artificial. In the latter, pumps or fans are used to drive air into or extract it out of rooms. In the former, open windows, valves or tubes are used as inlets, generally in combination with open fires which extract air from the room.

The gaseous impurities of air have already been enumerated, but in relation to ventilation carbon dioxide, which is produced in large quantities both by the respiration of human beings and other animals and by burning lights, is the most important, and is taken as a measure of the degree of vitiation of the air.

In natural ventilation the purity of air in a living room is maintained by employing the natural forces which set the air in motion; wind, and currents of air caused by differences in the temperature of the air inside and outside. There must be inlet and outlet, for air cannot go in and out of the same opening. In natural ventilation windows and doors, valves or tubes, generally used in combination with open fire places, are used as inlets and outlets.

Artificial ventilation involves the propulsion or extraction of air; there must be a plenum or vacuum in the room, and in order to establish this revolving fans, bellows and ventilating ducts are used. The chief advantage of artificial ventilation is that it is more regular, that air can be better controlled as regards heat, moisture and purification, and that the volume of air can be regulated; but, on the other hand, a system wrongly applied may give bad results. If inlets and outlets are badly placed the air may be driven through the room, leaving the greater volume of the air in it unaffected.

In an ideally perfect system of ventilation, the air in a room would be as pure, and would contain no more carbon dioxide than the air out of doors. But, as has been said, the amount of carbon dioxide in the open air varies, and a slight excess in a room is not noticeable; a room may be considered well ventilated if it contains not more than 1 part in 5,000 (2 in 10,000) of carbon dioxide more than the open air. This is called the limit of respiratory impurity.

To maintain the air of a room within this limit, every adult person in it must be supplied with 3,000 cubic feet of fresh air every hour,* and the same amount must be removed from the room in the same time. Children being smaller, require less, and half the amount, or 1,500 cubic feet an hour, may be taken as a rough average for them.

The air of a room cannot be changed by any natural system of ventilation more than three times in an hour without causing

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* The calculation on which this estimate is based may be thus stated. If a man exhaled 1 cubic foot of carbon dioxide in an hour, he would increase the amount in 5,000 cubic feet of air by 1, which is the limit of respiratory impurity (1 in 5,000). But it is assumed that a man at rest exhales $\frac{6}{10}$ths of a cubic foot, and he will therefore vitiate $\frac{6}{10}$ths of 5,000 = 3,000 cubic feet. A man at work exhales more than 1 cubic foot an hour.

draughts. Every adult, therefore, ought to have an air space of one-third of the amount of fresh air required hourly; as this is 3,000 cubic feet, the amount of air space for each adult in a room should be 1,000 cubic feet, or for a child 500.

It is not sufficient to consider the cubic space alone; the amount of floor space must also be taken into account: there must be enough space around each person in a room to allow free circulation of air. Mere loftiness of a room cannot make up for cramped floor space. It is well known that the air at the bottom of an open well may be poisonous, and many accidents have occurred to workmen who have gone down wells without taking proper precautions: people have fainted and even been suffocated in a crowd in the open air. There must be some limit in height, for the air above a certain limit is not available; the rule is, not to take into account anything beyond 10 or at most 12 feet in height in calculating the cubic space of a room. The floor space of a room 15 feet long by 11 feet broad will be 165 square feet, and its cubic space, taking the height at 12 feet, will be 1,980 cubic feet ($165 \times 12 = 1,980$). Such a room if properly ventilated—that is to say, if the air be changed three times an hour—will be about large enough for two adult persons, provided that it is not blocked by bulky furniture, which takes up air space. A cupboard, for instance, 6 feet high, 4 feet wide and 3 feet deep, occupies 72 cubic feet, and a single bed with its bedding from 10 to 20 cubic feet. It must also be remembered that a large supply of fresh air is required when lights are burning, for an ordinary gas-jet (batswing) gives off as much carbon dioxide as a man, or even more. Further, both human beings and burning lights are constantly adding watery vapour to the air; in a warm room in cold weather this vapour condenses on the window panes and runs down in drops, and may even make the walls damp. Animals kept in a living room also vitiate the air in the same way as human beings. Finally, all animals, including man, give off certain emanations from the skin and with the breath, which, if not removed by ventilation, give the air of the room a close, stuffy smell, while dirty floors, dusty carpets and soiled clothes all contribute to the vitiation of the atmosphere.

By ventilation, then, is meant a complete and continuous change

of air in a room, so that the amount of respiratory impurity shall never exceed the standard. The points to be taken into consideration are the purity of the in-coming air, its temperature and degree of humidity, as also the avoidance of draught: and the expulsion or bad air from the room.

Heating.

Heating and ventilation can hardly be treated separately. A room should be kept at as even a temperature as possible, 60° F. being a fair heat; a thermometer should be kept in every school-room. In practice, rooms are heated by open fire-places, closed stoves, hot air, or by hot water or steam pipes. Closed stoves are more economical, but, as they do not assist ventilation to any appreciable extent, are less healthy than open fire-places. They tend to make the air dry, but this disadvantage can be obviated by placing a bowl of water upon them. If gas stoves or fires are used, it is essential that special provision should be made for ventilation; they are not to be recommended for school-rooms. Warming by hot air driven into the room is a costly method of heating, but if properly carried out combines efficient ventilation with heating. Hot water pipes are a satisfactory method of warming rooms, provided adequate provision is otherwise made for ventilation.

The measure of respiratory impurity of school air may be taken to be in proportion to the amount of carbonic acid gas which it contains. It is not unreasonable to fix the maximum permissible for healthy conditions at 10 parts in 10,000 vols.

Judged by this standard, the majority of schools are defective. Most are ventilated by trusting to climatic conditions, and to the air exchange effected by differences in the temperature of the outer air and inside air, acting through open doors and windows; in some, Tobin's tubes are used as an additional inlet; open fire-places, and less frequently closed stoves with flues, act in varying degree as extraction outlets and help materially to purify the air. But for a greater part of the year these means are insufficient, and the school-rooms are stuffy and unhealthy. During the summer term ventilation exchange is very much reduced, and in winter there are complaints that if the windows are opened cold draughts pour into the room.

The same objection applies, though not to the same extent, to Tobin's tubes. By a Tobin tube, the air is introduced through horizontal shafts under the floor direct from the outside, and is delivered into the room by vertical tubes opening from six to nine feet from the floor. The air propelled through these tubes ascends and then curves imperceptibly downwards. One drawback to them is that they become clogged with dirt and cobwebs; and there is also the difficulty of heating the air. In consequence, it is not unusual to find one of these inlets carefully covered by a book.

A good kind of inlet is that known as Sherringham's valve. This is a sort of iron box in an outer wall, so constructed that the air is admitted through perforated brick or grating and directed upwards towards the ceiling by a valve. This valve can be opened or closed by means of a balanced weight. As the inner aperture of the ventilator is larger than the outer, the air penetrates into the room with less velocity than when it passed through the outer grating. What further renders the Sherringham valve a valuable form of every-day ventilation is that on occasion it can act as an outlet. There is the additional advantage that it can be easily put into existing rooms.

An open fireplace greatly assists ventilation. When a fire is burning in it, it extracts air at the rate of four or five feet a second. If a fire smokes, it is an index that the inlet of pure air is insufficient, and when a window is opened and a proper air supply given, the fire generally stops smoking. What renders a chimney useful as an outlet-ventilator, even when there is no fire in the grate, is the aspirating or drawing influence of the wind as it passes over the top of the chimney pot, causing air movements in the shaft. On a calm day, when no fire is burning, the extracting or ventilating ceases. In a sick room a fire, no matter how small, or a lamp kept burning in the grate acts as a purifier by extracting foul air. The air movements depend upon difference in its warmth, and the foul air disappears up the chimney. The warming of fresh air before it enters a room in cold weather, enables the occupants to bear a much larger quantity than they perhaps otherwise could. An excellent means of warming outer air is by a grate invented by Sir Douglas Galton and bearing his name. At the back of the grate is an opening to the outer air covered by a grating, through which fresh

air passes into a shaft passing up the side of the chimney flue. In the shaft it is warmed by the heat which ascends the chimney, and the warmed fresh air is admitted into the room through a grating near the ceiling. In hospital wards the grate is generally placed in the centre of the ward so as to allow the air to be better dispersed.

Efficient school ventilation is a subject upon which much careful thought and money have been expended; in spite of this it is still in a very unsatisfactory state. To introduce elaborate systems of ventilation into existing buildings is impossible, because the school houses may not be adaptable to them. In Aberdeen, the air is carried into the school rooms by fans on a propulsive system; but this would be very expensive and almost impossible to carry out in most present buildings. This being so, the teacher must understand something about the question of ventilation.

When air is heated, it expands; when cooled, it contracts. Hot air rises to the top of the room, and moist air also rises, the vapour of water being lighter than air. Cold air falls to the lower part of the room. It follows that the openings to let bad air out should be at the top of the room and those to let in good lower down. This points to the proper use of an ordinary English window. Most people are quite satisfied to open the window from the top, the idea being that fresh air pours in and that the foul air is carried up the chimney. We have already pointed out that the essentials of ventilation are inlet and outlet. In a room with the door shut, and the window open at the top and closed at the bottom, it will be found that the flame of a match or candle held at the open top blows outwards, proving that the bad air is propelled out of the room. If the window is then opened at the bottom too, and the flame held at the lower half, it will be found to blow inwards, proving that good air is entering the room through the lower part of the window. Let every teacher remember then that the best ventilation to be got from an ordinary window is by keeping it open both top and bottom. For very cold weather, in a badly-heated school-room, better than nothing is a board placed below the lower sash; this raises it a few inches, and allows the air to enter in an upward direction between the upper and lower sashes. This plan, known as the Hinckes-Bird ventilator, also provides slight ventilation at night. One reason why five or ten minutes' recreation in the

school-yard or school-hall between each lesson is so strongly to be recommended, is that the doors and windows can be thrown open and the class-room wind-swept. This materially lessens the foulness of the air. One particular girl can undertake the task of opening and shutting after each lesson.

In the early morning the school-room doors and windows should be thrown open top and bottom before the children arrive, and the teacher should do this again between morning and afternoon school, and again before leaving in the afternoon; the school keeper must be warned always to leave a portion of the windows open at the top at night. Impure air conduces to the spread of infectious diseases: measles, scarlet fever, diphtheria, tuberculosis; it is the cause of low vitality, headaches and fatigue, and reduces the benefits of education. If teachers realised its importance to their own health, to the vitality of the children, to their mental impressibility, and to their capacities as scholars, they would use their intelligence and reasoning powers to utilise as well as possible the means they have at their disposal for ventilating school-rooms.

V.—DIGESTION AND FOOD.

The Digestive System—The Mouth—The Teeth—The Salivary Glands—The Secretion of Saliva—Action of Saliva—The Stomach—The Gastric Juice—The Small Intestine—The Liver—The Pancreas—Composition and Action of Bile and Pancreatic Juice—The Large Intestine—Intestinal Bacteria—The Utilisation of Food by the Tissues—Food—Classes of Food—Energy Value of Foods—Diets—Meat—Bread—Legumes—Fruits and Vegetables—Cost of Foods—Cooking—Chemistry of Cooking—Cooking of Meat, Fish and Vegetables—Food and Diseases—Water, Composition, Sources—Beverages, Water, Aerated Waters, Tea, Coffee, Cocoa, Chocolate, Beer, Wine, Brandy, Gin, Whisky—Effects of Alcohol upon the Stomach, Upon the Intestines, Upon the Liver, Upon the Blood, Upon the Vaso-Motor Centres, Upon the Respiration, Upon the Circulation, Upon the Nervous System—The Social and Moral Aspects of Alcoholism.

THE DIGESTIVE SYSTEM.

The Mouth.

The mouth is formed by the lips and cheeks in front and at the sides, by the tongue below, and by the palate above. The front part of the palate, formed of bone covered with mucous membrane, is called the hard palate; the back part, called the soft palate, consists of two layers of mucous membrane enclosing a thin sheet of muscle. The hard palate is normally a flat arch, but when the nose is not well developed it is more or less high and narrow. The lips and cheeks are composed externally of skin, internally of mucous membrane, and between the two are muscles, vessels and nerves, and more or less fatty tissue. The red border of the lips is formed of a special kind of mucous membrane, which, unlike other mucous membrane, is normally dry.

The tongue is a muscular organ covered with mucous membrane. The posterior muscles spring from the hyoid bone, a thin, horse-shoe shaped bone, which may be felt at the front of the

neck under the chin and above the thyroid cartilage. It is suspended from the tips of the styloid processes of the temporal bones by the stylo-hyoid ligaments. Inferiorly, the tongue muscles are connected indirectly with the lower jaw. The tongue is an extremely mobile organ, and is covered on the upper surface or dorsum by a specialised mucous membrane.

Every part of the tongue possesses ordinary tactile sensibility, which is exceedingly acute at and near the tip. The sense of taste resides chiefly towards the root, and is specially associated with a set of large papillæ, ten or twelve in number, easily seen at the back of the tongue, disposed in a V-shaped row, with the apex backwards. Each has a broad top and a narrow base implanted at the bottom of a pit, so that the flat top projects a little above the surface of the tongue. The whole has a fancied resemblance to a castle with its ditch: the pit is called the fossa (ditch), its sides the vallum (wall), and the papillæ are therefore termed circumvallate. In the pit, on the sides of the papillæ and the vallum, are minute flask-shaped bodies called taste buds, consisting of clusters of specialised epithelium cells. The taste buds receive branches of the glosso-pharyngeal nerves, and are the principal organs of taste. The rest of the upper surface of the tongue is covered with conical papillæ set close together like velvet pile, the majority ending in a conical cap of epithelium, but in a few the cap is split into a bunch of filaments (filliform papillæ). Scattered here and there among the conical papillæ are large rounded, so-called fungiform, papillæ set in pits. Taste buds are found in these and also here and there in the mucous membrane of the tongue, especially at the back and sides; they occur also on the under surface of the soft palate and on the epiglottis.

The Teeth.

A tooth consists of the crown, the root and the neck. The crown is that portion of the tooth which is seen; the root is embedded in the gums and jawbone and has one or more fangs. The neck is that portion which joins together the crown and the root.

Everyone has two sets of teeth, the temporary, or milk teeth, and the permanent. When the permanent teeth appear, the temporary drop out one by one to make way for them.

The temporary teeth number twenty: four incisors, two canines, and four molars above and below.

The permanent teeth are thirty-two in number. The incisors, so-called because they are used to cut or divide food, are the four front teeth in each jaw; they have chisel-shaped crowns. The canine teeth, two above and two below, are next to the lateral incisors; their crowns are thick and conical. There are two bicuspids next the canines on each side, above and below; they are shorter and smaller than the canines, the crown being broader. The molar teeth or grinders are twelve in number, three on each side above and below; the last of these to come are the wisdom teeth, so-called, perhaps, because they appear much later than the others. The molar teeth are broad and uneven, and admirably suited for grinding and crushing food. Each tooth is hollow within, the interior of the crown being filled with a vascular sensitive substance known as the dental pulp, containing nerves and blood vessels which enter the aperture at the point of each fang.

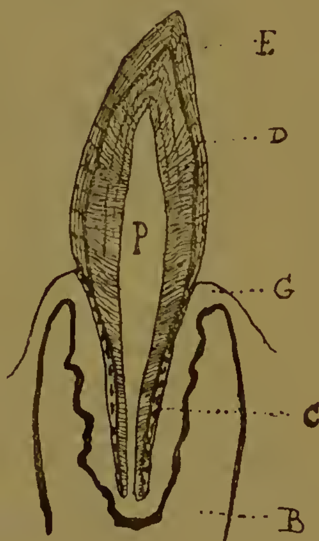


FIG. 3.—DIAGRAM OF STRUCTURE OF AN INCISOR TOOTH (VERTICAL SECTION).

E, enamel; D, dentine; C, cement covering the fang; P, pulp cavity, ending below in a narrow channel through which the nerves and blood-vessels enter; B, bone of jaw; G, gum; between B and C is the periosteum of the bone, through which the blood-vessels run downwards to enter the aperture in the fang.

The hard part of the tooth is composed of dentine (ivory), enamel and cement. The dentine which forms the greater part of the tooth resembles bone in appearance and chemical constitution, although its structure is not the same. The enamel is the outer hard white covering which protects the crown of the tooth; it is

composed of compact microscopic columns packed closely together, and is the hardest substance in the body, being as hard as quartz. The cement is a layer of true bone which covers the whole fang.

The permanent teeth have begun to be formed before birth, and calcification has already started in some of them. It is proceeding during infancy, so that a defective diet may very injuriously affect their development. An adequate supply of lime salts is as necessary for the proper formation of dentine as for the formation of bone. Most of the starchy foods are very deficient in lime salts, and therefore quite unsuitable as the staple diet of an infant in whom both bones and teeth are rapidly developing. This is one reason why milk is to be preferred to any other diet.

Eruption of the Temporary Teeth.

Central incisors, lower jaw	6 months.
" " upper "	7 to 8 "
Lateral " both "	8 to 10 "
Front molars " "	12 "
Canines " "	14 to 20 "
Back molars " "	18 to 36 "

Eruption of the Permanent Teeth.

Molar, first	6 years.
Incisors, central	7 "
" lateral	8 "
Bicuspids, anterior	9 "
" posterior	10 "
Canines	11 to 12 "
Molars, second	12 to 13 "
" third (or wisdom)	17 to 25 "

The permanent teeth appear somewhat earlier in the lower jaw than in the upper.

The two principal diseases of the teeth and gums are dental caries and oral sepsis. Dental caries is the ordinary decay of teeth, but oral sepsis is much more serious, since it has been proved that it may indirectly cause such diseases as pneumonia and diphtheria. The percentage of children in elementary schools with dental caries is very large; it often attacks the temporary teeth, and these infect the permanent ones when they come into

contact with them. Caries seldom occurs on the smooth exposed surface evenly covered by the enamel which has the property of resisting the action of acids, but nearly always begins at the side of the teeth, or in pits and depressions commonly not lined with enamel. It is obvious that the accumulation and fermentation of food containing organisms is in great part responsible for it. The determining cause of dental caries is therefore to be found in the activities of microbes commonly present in the mouth.

The mouth is a mucous cavity, enjoying an equable temperature of about 99° F., moist, well supplied with air, and with an abundance of bacterial papulum; small wonder that micro-organisms find it a good incubating chamber, and grow and multiply in it with great rapidity. More than one hundred different kinds of bacteria have been found in the juices and deposits in the mouth.

The two chief kinds of bacteria to be looked out for are those which attack and destroy the teeth, and the microbes which produce disease not only of the mouth, but of other organs; these are the specific bacteria, such as those of diphtheria and pneumonia, and microbes producing inflammation of the gums, throat and tonsils, serious disorders of the gastro-intestinal tract and general systemic infection. Inflammation of the gums may lead to inflammatory enlargement of the glands of the neck, which sometimes ends in abscess or paves the way for local tuberculosis.

There is good reason to believe that severe types of anæmia are due, more or less directly, to septic conditions of the mouth; and the continual swallowing of infective matter has a most injurious effect on the general health. Carious teeth mean wearing pain, loss of rest, and imperfect mastication of food, with consequent imperfect digestion and defective nutrition.

The predisposing causes of caries are heredity and mal-nutrition: the determining cause the general neglect of the mouth. Many experts consider that improper feeding in infancy on patent foods instead of on pure milk affects the teeth very seriously, interfering with the regular process of calcification in permanent teeth. Once a tooth is formed, nothing will change it for the better, and damage done in the process of calcification can never be undone,

Mischief may be much increased by neglecting to brush first teeth; they may become carious when neglected and food allowed to lodge between them.

Experiments have been made to discover which foods are most injurious to the teeth: starchy, saccharine, albuminous or fatty. Sound, natural teeth were placed in a mixture of human saliva and bread and sugar, and kept in an incubator at body temperature for a prolonged period, with the result that the mixture became strongly acid and the teeth carious, with exactly the same appearance as carious teeth in the mouth. This was due to the fermentation of carbohydrates, giving rise to the production of lactic acid, which decalcifies dentine. It was found that if sound teeth were placed in a mixture of saliva with albuminous and fatty food, from which carbohydrates were excluded, the result was decomposition and a strongly alkaline reaction, but the teeth were not attacked by caries; the alkalinity was due to the decomposition of albumen. Lactic acid alone will not produce caries, and it is to be inferred that the micro-organisms in the saliva and lactic acid together do the mischief; for, as has been said, many bacteria found in the mouth can dissolve albuminous substances. The decay of teeth takes place in two distinct stages: (1) decalcification of the dentine, and (2) dissolution of the softened animal basis.

It is urgent that the teeth and gums should be carefully brushed night and morning with a very stiff brush and some simple antiseptic tooth powder, in order to dislodge the particles which may have got embedded between them. Night is, of the two, the more important time, for in the daytime the movements of the tongue and lips in a measure prevent the accumulation and fermentation of food in the mouth. It would be well for teachers to explain how injurious many of the advertised dentifrices are, especially liquid dentifrices. Castille soap, percipitated chalk, or something equally simple, is all that is required. Cold water may be recommended as strengthening the gums.

For children of the poorest classes, who have little chance of being encouraged in their homes to care for their teeth, toothbrushes should be supplied by the State, and teachers should hold a daily inspection of the scholars' teeth and insist upon their being brushed regularly and thoroughly. Each child could have a locker

with its name upon it, in which an enamelled mug, a tooth brush and some simple tooth-powder could be kept.

The ignorance that prevails about the teeth among the labouring classes is appalling. They never dream of saving a tooth by having it stopped ; they wait until it is absolutely decayed, and then if it becomes very painful they have it extracted. Consequently they suffer from indigestion, which is often caused by the swallowing of the infective secretions of the carious teeth, coupled with imperfect mastication due to the loss of many teeth. Food not well masticated is not easily acted on by the gastric juice; it is imperfectly digested and undergoes decomposition, leading eventually to dilatation and chronic inflammation of the stomach.

SALIVARY GLANDS.

The saliva which flows into the mouth during eating is secreted by three pairs of glands :

(1) The parotid gland lies on the side of the face in front of the ear; it is the largest of the salivary glands. Its duct, about two and a half inches long, opens on the mucous surface of the cheek, opposite the second molar tooth of the upper jaw.

(2) The submaxillary gland is a rounded body which lies immediately below the angle of the lower jaw; its duct opens into the floor of the mouth near the middle line.

(3) The sublingual gland, the smallest of the three, is a long narrow body which lies under the tongue, where it may be felt as a ridge between the tongue and the gum; it has several ducts which open separately into the floor of the mouth.

Structure of Salivary Glands.

The salivary glands are typical examples of secreting glands, and belong to the compound tubular type. If the main duct be followed by dissection into the substance of the gland, it is found to divide again and again into a multitude of smaller and smaller branches. The finest terminal twigs open into the secreting tubes called acini (Fig. 4, I.), which consist of a basement membrane, lined by the secreting cells and surrounded outside by blood vessels.

The secreting cells of the salivary glands are of two main types, according as the secretion of the gland is mainly serous or

albuminous (parotid), mainly mucous (sublingual) or both (submaxillary). In a gland that has not recently been secreting, the mucous secreting cells, which are round or oval, are distended with a clear substance, mucigen, from which mucus is formed when the gland becomes active. The cells of the glands which yield an albuminous secretion are cubical and almost fill up the acini. Their protoplasm is full of dark granules before secretion occurs; when it

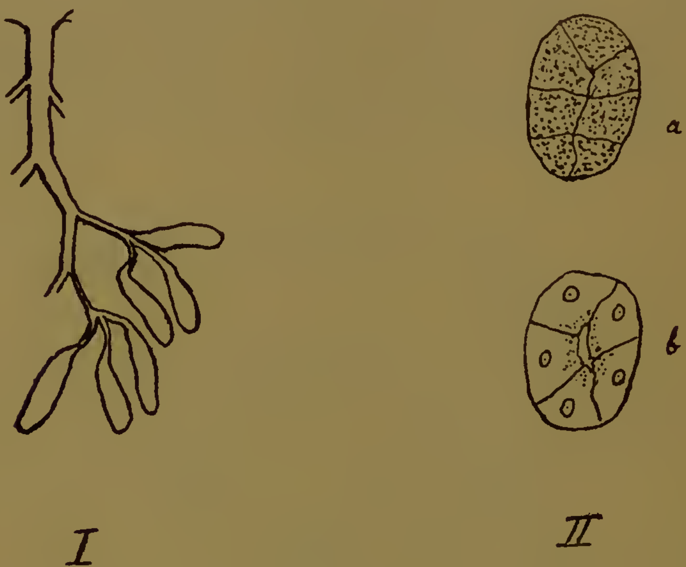


FIG. 4.

I.—DIAGRAM OF STRUCTURE OF SALIVARY GLAND.

II.—SECTION OF ACINUS OF SALIVARY GLAND.

a, after rest, showing numerous dark granules; b, after a long period of activity the granules have nearly disappeared, allowing the nuclei of the cells to come into view.

begins, the granules diminish in number and finally almost completely disappear. (Fig. 4, II.).

THE SECRETION OF SALIVA.

The secretion of saliva is a reflex act under the control of the nervous centre. The reflex is started (1) by the act of mastication through the nerves of the tongue, (2) by the taste or smell of food

through the nerves of those senses, (3) by the entrance of food into the stomach through the pneumogastric nerve, and (4) even by the thought of food, that is, by the direct action of the higher centres of the brain; the drying up of the saliva caused by the emotion of fear is due also to the action of these centres.

The nervous action is double: direct on the secreting cells, stimulating them to secrete: and indirect, by causing the blood vessels to dilate, and so increasing the flow of blood through the glands.

Composition and Properties of Saliva.

The fluid secreted by the different salivary glands differs slightly. That from the parotid contains no mucus, that from the submaxillary some, that from the sublingual more. The characteristic digestive ferment of the saliva is contained in the secretion of the parotid and submaxillary glands.

The saliva in the mouth, which is incorporated with the food during mastication, is a mixture of the secretion of the three pairs of salivary glands, and of some small mucous glands in the mucous membrane of the mouth.

The mixed saliva is a tasteless, colourless, opalescent, slightly ropy fluid, with a specific gravity of 1002 to 1006. It is alkaline, from the presence of alkaline phosphates; in the small hours of the night it may be faintly acid; in digestive disorders and in fever it may be distinctly acid. The quantity secreted daily varies very much, but averages probably from one to two pints. It contains some small, spherical cells called salivary corpuscles, shed epithelium from the mouth, and various kinds of microbes, as a rule in large numbers. They live upon the shed epithelium, the remains of food lodged between the teeth, and in decayed teeth. In a person careless of the cleanliness of the teeth and mouth they may be present in such large numbers that, by the decomposition and fermentation they produce, the saliva in the mouth is rendered acid, and this is one of the chief causes of the decay of teeth.

Chemical Composition.

The mixed saliva contains albuminous substances, mucus, a special ferment (ptyalin), and a number of salts, including sodium chloride (common salt), potassium chloride and sulphate and

alkaline and earthy phosphates. When drugs containing mercury, iodine, bromine, lead or morphine are taken, these substances are secreted in the saliva.

Action of Saliva in Digestion.

Ptyalin, a ferment which renders starch soluble by converting it into dextrin and sugar, is the most important constituent of saliva. If the action is continued long enough, the dextrin is all converted into sugar (dextrose); the change occurs most quickly at about the temperature of the body. Ptyalin acts only in alkaline, neutral, or feebly acid fluids, but it continues to act for some time in healthy gastric juice. Starch consists of grains, varying in size and shape according to its source. The starch grains of potato, for instance, are, on an average, three or four times as large as those of cornflour. The form and size of a grain of starch is fixed by layers of cellulose, a substance insoluble in water or saliva; when boiled the grains swell up and burst, so that the starch is more easily acted on by the ptyalin; when thoroughly boiled or ground, all kinds of starch are dissolved by ptyalin with about equal rapidity. Its action is favoured by the presence of common salt, but hindered by strong alcohol.

At birth the salivary glands are disproportionately small, and ptyalin is formed in small quantities by the parotid gland only. As milk contains no starch, but in its place a special kind of sugar (milk sugar or lactose), ptyalin is not necessary to its digestion. This peculiarity affords an explanation why starchy foods are unsuitable to infants. At about the time when the first set of teeth begins to be cut, the salivary glands increase rapidly in size.

The saliva also dissolves other soluble substances in the food, moistens food taken dry, and, owing to the mucus it contains, facilitates the swallowing of food.

The Fauces and Œsophagus.

The fauces, or opening from the mouth into the pharynx, is an arch from the centre of which hangs the uvula. The sides of the arch are called the pillars; each pillar divides into two towards the base, and between these on either side is the tonsil. The pillars are strongly contracted in swallowing; when the mucous membrane over

them, or the tonsils between them, are inflamed, the contraction causes the acute pain that accompanies sore throat. Repeated inflammation of the tonsils may produce enlargement so great that they almost meet across the fauces, and obstruct breathing through the mouth.

The Pharynx (q.v.) ends in the gullet or *œsophagus*, a hollow, muscular tube lined with mucous membrane, which passes down the neck behind the larynx, through the chest, behind the root of the left lung, and traverses the diaphragm to open into the stomach. The food is carried down it by peristaltic action.

Peristalsis is the term applied to the movements of the intestines and certain other hollow muscular tubes. By the contraction of the muscles at one level a circular constriction is formed, the contraction passes down like a wave, and anything within the tube is squeezed downwards. The wave of contraction is called the peristaltic wave.

The Stomach.

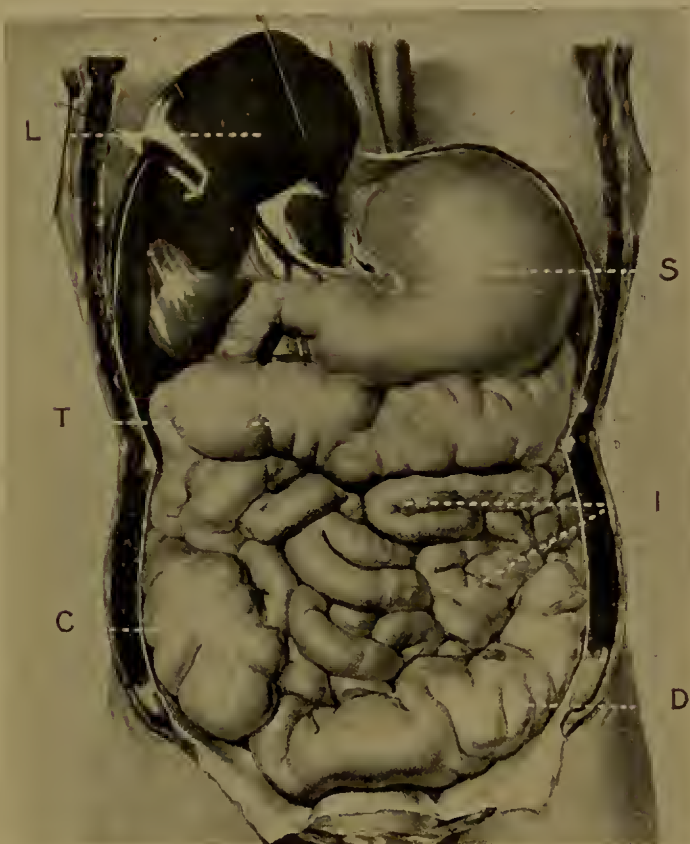
The stomach is a specialised and much expanded part of the alimentary canal, where the food is subjected to the action of the gastric juice, an acid fluid containing a special ferment, pepsin.

The stomach has an irregular pear-shaped form. It lies obliquely in the upper part of the left side of the abdomen, and is partly under cover of the ribs. The broader end is towards the left, and the gullet enters into this part of the stomach, called the cardia or cardiac end owing to its proximity to the heart, from which it is divided only by the diaphragm and pericardium. The upper concave curve is called the lesser curvature, the lower convex the greater curvature. The orifice by which the stomach communicates with the small intestine is called the pylorus; it is a circular opening surrounded by a ring of strong muscular tissue, by the contraction of which it is kept closed, except when the partly digested food is to be allowed to pass out of the stomach. The stomach has soft elastic walls, and of course, varies very much in size according to the amount of food in it. A fair idea may be gained by assuming its average dimensions in the adult to be about 12 inches long, 6 inches broad, and 4 inches deep (from back to front), and its capacity two or three pints. At birth the stomach will hold about two or three tablespoonfuls of milk; it

PLATE X.

Drawing to Show the Position of the more important Abdominal Organs. (*After Sappey.*)

L, Liver; **S**, Stomach; **I**, Small Intestine; **C**, Cæcum; **T**, Transverse Colon; **D**, Descending Colon.



Abdominal Organs.

enlarges rapidly, at three months old will hold seven or eight tablespoonfuls, and at a year old nearly half a pint.

The stomach has four coats: (1) an external serous covering reflected from the peritoneum; (2) the muscular coat; (3) the submucous coat of loose areolar tissue; and (4) the mucous membrane. The two external coats are elastic, and the exterior surface is smooth, even when the organ is empty. The mucous coat is much less elastic, and the looseness of the submucous coat allows it to fall into many wrinkles. The muscular coat consists chiefly of circular fibres, which pass round the stomach and, by their contraction, tend to make it more tubular. There are also some oblique muscular fibres, which run from the neighbourhood of the œsophagus downwards and to the right, towards the greater curvature, and a few longitudinal fibres chiefly along the lesser curvature.

The arteries, which are very numerous, ramify in the submucous coat, and send branches into the mucous membrane. At the base of the mucous membrane is a thin layer of muscle fibres, the muscularis mucosæ, and there is a scanty supporting structure in the membrane proper, but its thickness is made up chiefly of the glands, blood vessels, and lymphatics. The small arteries run from the muscularis mucosæ towards the surface; in their course they first form a capillary network round the glands, and then another just under the surface epithelium. The first network supplies the glands with material for the manufacture of gastric juice, the second carries away the foodstuffs dissolved by the gastric juice in the stomach, and absorbed by the epithelial cells. This superficial capillary network is collected into vessels, opening into numerous large veins in the submucous coat. The lymphatics begin by looped or bulbous blind ends near the surface, and follow a similar course to the veins.

Structure of the Gastric Mucous Membrane.

The mucous membrane of the stomach is in reality a large secreting gland, its parts being spread out and having a multitude of ducts opening on the surface, instead of being packed together with the ducts opening into one common tube or large duct, as is the case with the salivary glands. The mucous membrane is covered by a layer of columnar epithelium, and the surface in

health has a smooth glistening appearance. When slightly magnified it is seen to be marked everywhere by very numerous small depressions, the gastric crypts; the sides of the crypts are lined by curious elongated cells, called goblet cells. The stem is protoplasmic, and has a nucleus, but the bowl contains clear mucus and has an open mouth. (Fig. 5, G.)

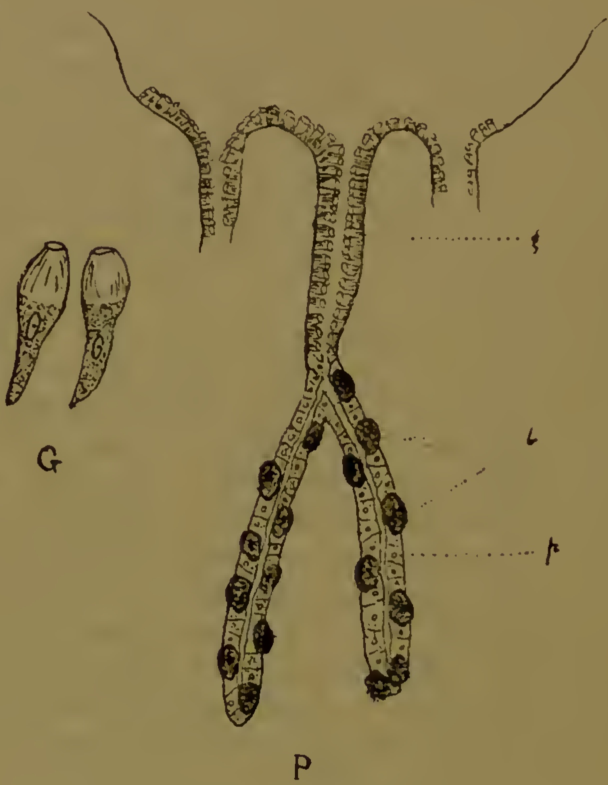


FIG. 5.—PEPTIC GLAND.

P, peptic gland; g, goblet cells; p, peptic cells; b, border cells which secrete hydrochloric acid. G, goblet cells much magnified.

Opening into the bottom of the crypts are the true gastric or peptic glands; they number about five millions in the adult, eight or ten opening into each crypt. A peptic gland (Fig. 5, P.) is a short tube, lined by cubical or wedge-shaped cells, consisting of granular protoplasm from which pepsin is formed; they are called the chief cells. Scattered amongst, but chiefly outside the

chief cells, are some larger oval cells, called from their position border cells; they are traversed and surrounded by a minute net-work of passages which unite to form a microscopic duct; this opens into the tubular cavity of the peptic gland; these cells secrete hydrochloric acid.

In the neighbourhood of the pylorus the glands are simpler in structure, with longer ducts and shorter secreting tubules. They are lined by granular secreting cells.

The Secretion of Gastric Juice.

The secretion of gastric juice is in part a reflex action through the pneumogastric nerve. The sight of food, or the chewing of food without swallowing it, is followed in a few minutes by dilatation of the blood vessels of the stomach, and a flow of gastric juice. But the secretion is mainly induced by the actual contact of food with the mucous membrane of the stomach.

Composition and Properties of Gastric Juice.

The gastric juice is a colourless, nearly clear, watery fluid with a strong acid reaction, an acid taste, and a characteristic odour. During digestion its specific gravity is 1010 to 1020. The amount secreted daily, measured by weight, is said to be equal to about one-tenth of the weight of the body.

Pepsin, the characteristic ferment of gastric juice dissolves proteids; it is present in the proportion of half to one per cent. It is secreted by the chief cells of the peptic glands, which become less granular during the process, and also by the pyloric cells, though in small quantity. Pepsin does not exist as such in the cells. They contain a pepsinogenic substance, not itself capable of digesting proteid, but converted into pepsin by hydrochloric acid or sodium chloride. Rennet, a ferment coagulating milk is also present, especially in the gastric juice of sucking animals.

Hydrochloric acid is present in gastric juice in the proportion of two or three parts in a thousand. The stomach, when empty, contains a little hydrochloric acid, but as soon as appetite arises or food reaches the stomach it is secreted abundantly. It not only aids the digestion of proteids, but stops putrefaction and checks other fermentations: it has therefore an antiseptic action. Microbes

entering the stomach with food or water in moderate numbers are actually digested and rendered harmless, so that the gastric juice is one of the chief defences of the body against such infectious diseases as typhoid fever, cholera, and tuberculosis. The old popular idea that it is safer to incur a necessary risk of infection after a meal, probably finds its justification in the fact that the gastric juice flows most freely and is most active when there is food in the stomach.

Gastric juice contains also certain salts, chiefly chlorides of sodium potassium and calcium dissolved in the water: mucus: and very often lactic acid. The pepsin and hydrochloric acid of the gastric juice transform proteids in the stomach, converting them eventually into peptones, readily soluble in water and very diffusible. They are very rapidly absorbed, but before being discharged into the blood vessels of the stomach are again transformed by the epithelium cells of the mucous membrane into albumen (serum albumen). This is carried by the portal vein to the liver, and its final purpose is to replace the proteids consumed by the activity of the tissues.

Meat is for the most part digested in the stomach, though some remains are passed into the duodenum, where digestion is completed by the pancreatic juice: white fish, chicken, raw scraped beef, soft-boiled eggs are very easily and quickly digested in the stomach; mutton, and even pork, more rapidly than beef or rabbit. The proteid parts of vegetables are more or less completely digested, and the starch granules liberated; cellulose is untouched. Bread is softened, its proteid parts digested, and probably much of the starch which has been changed during the making and baking absorbed.

The Small Intestine.

The small intestine communicates at its upper end with the stomach, and its lower end opens into the dilated upper part of the large intestine. The first part of the small intestine, called the duodenum (*duodene*, twelve), because it is about twelve finger breadths long, forms an S curve, and is bound down to the vertebral column. The next part of the small intestine, called the jejunum, because it is usually found empty, and the third part, called the ileum, are much more movable. In the adult, the total length of the

small intestine is about twenty feet, and its surface area rather more than half a square yard. Though actually smaller in children, it is, relatively to their height and weight, longer and more capacious as is to be expected, for a child has to absorb sufficient food not merely to live but to grow upon. The mucous membrane, which is clothed with columnar epithelium, is thrown into many thin folds, each reaching about half-way round, called valves (valvulæ conniventes). The mucous membrane is covered by many small projections, like velvet pile, called villi; by these means the total absorbing surface is increased to ten or twelve square yards. Outside the mucous membrane is a thin layer of loose connective tissue and then a muscular coat, consisting mainly of circular fibres, but with some longitudinal. Outside the muscular is the peritoneal coat which folds over, and at the inner edge forms a flat membrane called the mesentery, by which the intestines are fixed in position. As the mesentery narrows, or is, as it were, gathered in where it is attached to the back of the abdomen, the small intestine is not one long straight tube but is thrown into coils. In its upper part (duodenum and jejunum) the muscular coat is thicker and stronger, and the valves and villi more numerous. The chief duty of the small intestine is absorption: this is performed mainly by the villi, of which there are four or five millions. Each villus is formed of lymphoid tissue, and has in its centre a relative large lacteal (lymphatic) vessel (Fig. 6); it is covered by a layer of cylindrical epithelium, which contains some goblet cells. In the mucous membrane, most numerous where the villi are present, are a multitude of minute depressions each like the finger of a glove, called the crypts of Lieberkühn, after the eighteenth century anatomist who discovered them; they are lined by cylindrical epithelium and secrete the intestinal juice. In the wall of the duodenum is a sheet of gland tissue (Brunner's glands), which secretes a fluid resembling pancreatic juice. For some reason never quite explained, this sheet of gland tissue may become inflamed and ulcerated in consequence of severe burns or scalds of the skin. In addition to the villi other parts of the wall of the small intestine contain more or less lymphoid tissue; in the lower part (ileum) it is collected into groups of nodules called Peyer's patches. In typhoid fever these patches become inflamed and often ulcerate,

and it is these ulcers which constitute one of the chief dangers of the fever, and make it so imprudent to give a patient recovering from it solid food until convalescence is far advanced.

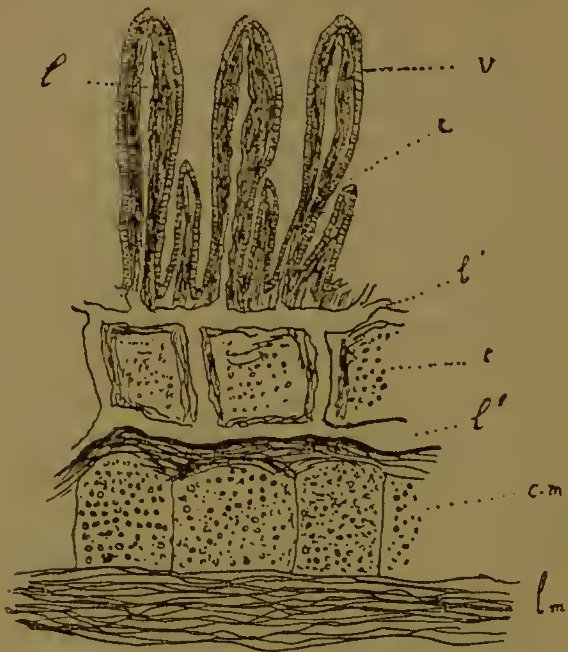


FIG. 6.—DIAGRAMMATIC DRAWING OF STRUCTURE OF WALL OF SMALL INTESTINE.

v, villi; c, crypt of Lieberkühn; l, lacteal in villus; l'l', lacteal plexus in the submucous coat; t, lymphoid tissue; c.m., circular muscle fibres; l.m., longitudinal muscular fibres.

The intestinal juice flows during digestion; it is an alkaline fluid, containing a good deal of mucus but possessing very slight digestive powers. Digestion is, in fact, completed high up in the intestine, where the chyme is acted on by the pancreatic juice and bile; the rest of the small intestine is designed to absorb the products of digestion.

THE LIVER.

The liver, the largest gland in the body, lies on the right side of the abdomen, and is for the greater part covered by the ribs, its rounded upper surface projecting into the chest; its under surface,

concave or almost flat, is in contact with the stomach and intestines. The liver has two lobes, right and left, and on the under surface of the right, much the larger, is the gall bladder or reservoir of the bile, a pear-shaped sac about three inches long, with a duct which joins the bile duct of the liver, forming the common bile duct, common, that is, to the liver and gall bladder.

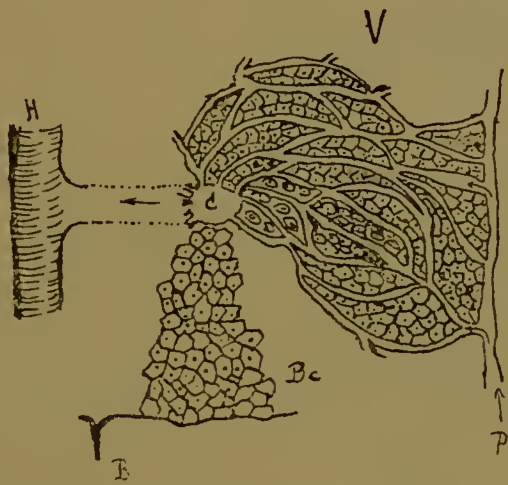


FIG. 7.—DIAGRAM OF THE CIRCULATION THROUGH A LOBULE OF THE LIVER.

P, interlobular (portal) veins; V, venous capillaries, passing between the liver cells and opening into the central vein, C, (intralobular vein), which opens into a branch of the hepatic vein, H, at the edge of the lobule; B, small bile vessels communicating with the fine intercellular network Bc. (The venous capillaries are shown in one part and the biliary in another, about one quarter of a lobule being represented.)

The liver is made up of a great multitude of small lobules, each one-twelfth of an inch in diameter, or less. The lobules are composed of irregularly cubical cells surrounded by a network of capillaries. The liver receives its blood from two sources, the hepatic artery, which supplies the arterial blood necessary for the nutrition of the liver cells, and the portal vein, a large vessel which brings the blood from the digestive organs. The portal vein on entering the liver, gives off many branches, its final smallest twigs being placed between the lobules, interlobular veins, where they open into the capillary network; these capillary vessels converge

and open into a rootlet of the hepatic vein, or intralobular vein, at the centre of the lobule. The small hepatic veins run from the lobule to open into larger vessels. These joining together as they run backwards through the liver, form the large hepatic vein, this ending in the inferior vena cava, which pours its blood into the right side of the heart.

The liver secretes bile, formed from the blood by the liver cells; these cells also have the important function of forming and storing sugar. Sugar is used up by muscles when they are in action; it is always present in the blood in about the same proportion, 1 in 1000, and this constant proportion is maintained by the action of the liver. The blood, which reaches the liver by the portal vein from the stomach and intestines during digestion, contains more sugar than other blood; this excess is taken up by the liver cells and stored, not as sugar but as animal starch, glycogen, which is insoluble. The stored glycogen is changed again by the liver into sugar, as required to keep the proportion of sugar in the blood 1 in 1000. Diabetes is due to a breakdown of this glycogenic function of the liver.

The liver cells also arrest poisons; mineral, such as arsenic, lead, and phosphorus; and organic, such as morphine and strychnine. They are taken out of the blood by the liver cells and retained by them. The liver cells possess also the power of modifying and destroying the toxins produced by microbes of disease.

To sum up then, it will be understood that a liver cell is nourished by arterial blood; it receives through the portal vein from the digestive organs crude blood, which it modifies and returns through the hepatic veins to the heart, to do duty in all the tissues of the body; and it secretes bile which leaves it to do duty in the intestines.

The bile is collected from the liver cells in small channels that run between them. These open into the smaller bile ducts that course through the substance of the liver with the portal veins, and, uniting with each other, appear on its under surface as a single duct; this soon joins the duct from the gall bladder to form the common bile duct: the latter opens into the upper part of the small intestine, or duodenum. The large bile ducts thus form a Y, one limb coming from the liver and the other from the gall bladder, the stem opening into the duodenum.

The Pancreas.

The Pancreas is a flat, narrow gland about six or seven inches long; it lies behind the stomach and intestines across the front of the vertebral column, and has a thick head to the right lying in

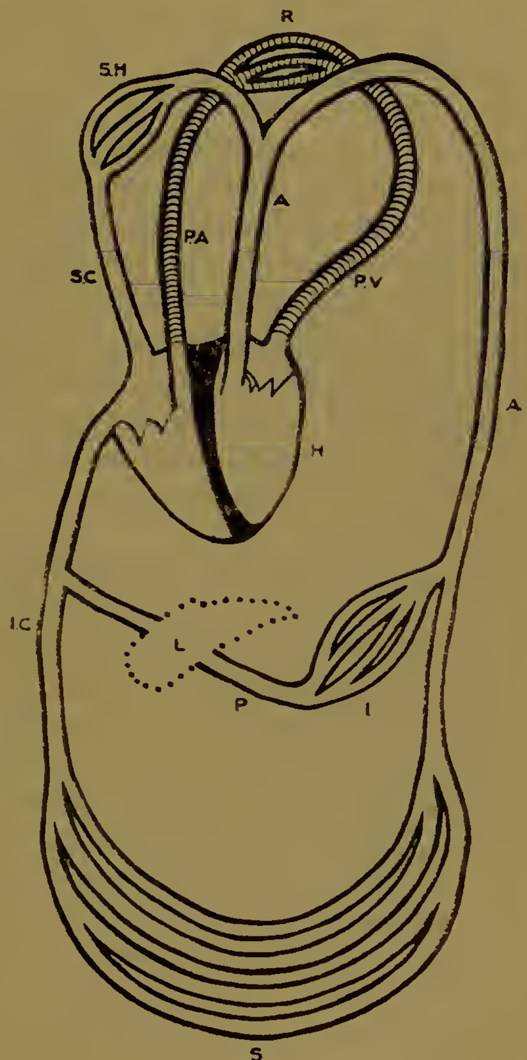


Fig. 8.—Diagram to Show the Relation of the Portal to the General Circulation.

H, heart; P A., pulmonary artery; R, circulation through the lungs; P V., pulmonary vein; A, aorta; S H., circulation through head, neck and upper limbs; S C., superior vena cava; S, circulation through trunk and lower limbs; I C., inferior vena cava; I, circulation through the stomach and intestines; P, portal vein; between L and I C hepatic vein.

the curve of the duodenum, and a thin tail reaching nearly to the spleen to the left. It is a branching or racemose gland, and in structure resembles a salivary gland, but the fluid it secretes contains three ferments acting on starch, on fat, and on proteid

respectively. This secretion, formed by the pancreatic cells, is collected by short transverse ducts which open into a long duct running the whole length of the pancreas; it passes through the wall of the duodenum, to open either along with, or very close to the common bile duct. In man, therefore, the bile and the pancreatic fluid enter the intestine already mingled, and as might be assumed from this fact alone, act together in digestion, the one supplementing the other.

Bile and Pancreatic Juice.

Bile is a semi-transparent yellow-brown ropy fluid, with a feeble musky odour and bitter taste. The colour is due to pigment (chiefly bilirubin), formed by the liver cells from the hæmoglobin of the blood, the ropiness to mucus, and the bitter taste to the two bile acids, glyco-cholic and tauro-cholic, which exist as salts in combination with sodium. The most important part played by bile in digestion is in promoting the absorption of fats. This it does by forming so fine an emulsion with them that the minute fatty particles can be taken up by the intestinal epithelium; the formation of this emulsion is favoured by the combination of the sodium of the bile salts with the fatty acids, produced by the action of the pancreatic juice on fats, to form soaps, themselves soluble. Bile also stimulates the peristaltic movements of the intestines, and has a slight antiseptic effect in checking putrefaction.

Pancreatic juice is a transparent, colourless, odourless, strongly alkaline, viscid fluid. It is secreted after food has been taken, and most copiously when the acid chyme is expelled from the stomach into the duodenum. The ferments it contains are:

Amylopsin, resembling the ptyalin of the saliva, and like it converting starch into sugar.

Trypsin, dissolving albumens and converting them finally into soluble peptones. Unlike pepsin it acts only in an alkaline fluid.

Steapsin, emulsifying fats and splitting them into their component parts, glycerin and a fatty acid.

The sugar formed in pancreatic digestion is absorbed into the blood, and carried by the portal vein to the liver. The peptones are taken up by the mucous membrane, discharged into the blood as serum albumen, and carried to the liver. The emulsified fat is

caught by the epithelial cells and passed through them into the lymphatic vessels, called here lacteals, because when active they look as if filled with milk (*lac, lactis*, milk) ; by the lacteals they are carried to the thoracic duct, by which they are discharged into the general venous circulation.

The Large Intestine.

The large intestine is, in the adult, about five or six feet long, and from 2 to 2½ in. in diameter. Its first part, which lies in the right iliac fossa, is called the cæcum, or blind end, because the small intestine opens, not into the extreme end of the large, but about 2½ in. further on (Plate X.). The opening is guarded by two folds of mucous membrane, called the ileo-cæcal valve ; this offers a certain degree of resistance to the regurgitation of fluid from the large to the small intestine. Opening into the back of the cæcum is a thin tube with a blind end, called from its supposed resemblance to a worm, the vermiform appendix (*vermis*, a worm). It is from 3 to 6 in. long, and is lined by mucous membrane like the rest of the intestine. Its use in the economy is unknown ; it seems to be a survival no longer useful. Appendicitis is due to inflammation of this appendix, and its removal, often necessary to cure that condition, appears to have no ultimate ill effect.

The large intestine is not thrown into coils like the small, but makes one wide horse-shoe curve. The first part, called the ascending colon, passes upwards from the cæcum to the under surface of the liver. It is then bent almost at a right angle, and passes across the front of the upper part of the abdomen to the right side : this is the transverse colon. It is then bent again and passes down the left flank as the descending colon, to the pelvis, where it terminates in a large coil called from its S shape the sigmoid flexure. This flexure opens into the rectum, the terminal part of the intestine.

The structure of the large intestine presents a general resemblance to that of the small, but the longitudinal fibres of the muscular coat form three strong bands, and these being shorter than the intestine itself, throw it into a series of puckers. These puckers show on the inside as sharp transverse ridges, and the wider parts between are called saccules. The mucous membrane,

which has a columnar epithelium, contains a large number of simple glands, like the crypts of Lieberkühn in the small intestine. These secrete mainly mucus. There are also many lymphoid nodules, most numerous in the cæcum.

In the large intestine the process of absorption is completed and the waste material, which in an ordinary diet may be estimated at from eight to ten per cent., is rendered semi-solid by the abstraction of water. The semi-solid material passes from the descending colon into the sigmoid flexure: this, in a healthy state of the digestive organs, is emptied by the daily action of the bowels. The natural stimulus is the entrance of food into the stomach which sets up peristalsis throughout the whole intestine, small and large.

Decomposition, due to bacteria, takes place very readily in the large intestine. This points to the necessity for regular habits, since in cases of habitual constipation, the large intestine contains poisonous products of decomposition which pass into the blood and produce toxæmia. The presence of decomposing matter in the cæcum is one of the chief causes of appendicitis.

By its mechanical action also, constipation causes congestion of the abdominal organs and hæmorrhoids. If children are taught habits of regularity they may be spared much suffering in later years.

Bacteria in the Digestive Trait.

So far, reference has been made chiefly to the changes in the food brought about by the true processes of digestion, but the alimentary canal from a day or two after birth contains many microbes; these, growing freely at the temperature of the body, produce various fermentations and putrefactive decomposition. Some of the microbes are harmless, perhaps useful, others more or less injurious, while others again are distinctly disease-producing, such as the bacilli of tubercle and typhoid fever. The number of microbes present in different parts of the alimentary canal varies very much. There are always some in the mouth, and if the teeth are not kept clean the number may be very large. The healthy gastric juice destroys microbes, both those swallowed in the saliva from the mouth, and those contained in food; but its power is not unlimited, and may be neutralised by the eating of food loaded with microbes, or if the saliva is constantly infected. Moreover, gastric

juice is only secreted when food is taken, so that microbes reaching the stomach from the mouth while fasting may escape destruction and multiply in the stomach, or pass through it to the intestines.

Among the bacteria almost invariably present in the upper part of the intestines and often also in the stomach, are the lactic acid bacillus which ferments sugar, including milk sugar, into lactic acid, and the butyric acid bacillus, which transforms lactic into butyric acid. The intestines also contain various bacilli having the power to ferment proteids. Among the bacteria most constantly present is that called the colon bacillus, because it is so constantly present in the large intestine, although it occurs also in the small. It has the power of fermenting both sugars and proteids, and if it gets from the intestines into other organs may produce abscesses. The colon bacillus is so characteristic an inhabitant of the intestines that its presence in water is held by bacteriologists to be strong evidence that the water has been in some way polluted by excrement.

Summary.

The final result of the processes of digestion is the transformation of the albumens and other proteids into soluble bodies, chiefly peptones, and of the starches into sugars; these, along with the salts, are dissolved in water taken with food. They are absorbed by the epithelium cells of the stomach and intestines, passed into the blood vessels, and carried by the portal vein to the liver. Fat is for the most part finely emulsified, and the minute particles are picked up by the epithelial cells and passed into the lacteals, and so by the thoracic duct into the general venous system.

The Utilisation of Food by the Tissues.

The way in which food is digested has been explained, and it has been shown how the products of digestion reach the blood, either directly by absorption from the stomach and intestines, or indirectly by the lacteal vessels of the lymphatic system (pages 45, 48 and 86).

The arterial blood carries to the tissues of all the organs the materials they require, both for producing energy and for replacing the waste, which, though small in amount, is constantly taking place in the tissues themselves. It supplies to the glands

the material out of which they form their secretions: to the stomach, for instance, the material for forming the gastric juice, and in childhood it carries to the growing organs, muscles, bones and so on, the material which they build into their substance during growth. From this point of view we may look upon the body as an engine producing energy, but an engine which repairs itself. When it ceases to repair itself efficiently, there is debility or actual disease.

The chief fuel of the engine is the carbohydrate in food. The complex molecule of the carbohydrate when it reaches the tissues is in the form of sugar; it is oxidised down to the simple molecule of carbon dioxide, and in the process energy is produced, just as in the furnace of an engine energy is produced by the combustion of coal. Fat also yields energy, but if the carbohydrates of the diet are sufficient for the demands on the energy of the body, much of the fat is stored up. During a long fast this store of fat is called upon. Fats when used for the production of energy are broken down, the final residue being carbon dioxide, as in the case of carbo-hydrates: the carbon dioxide from both sources is excreted by the lungs.

The proteids of food, converted into soluble peptones during digestion, and then into the plasma of blood, are also used up by the tissues; the carbon of the proteid forms carbon dioxide, which is excreted by the lungs; the nitrogen is oxidised into urea, a very soluble body excreted by the kidneys. A small part of the nitrogen is converted into uric acid, a less soluble body; its proportion is increased in fever, in some form of indigestion, and when the diet contains too much meat. During all these processes a certain amount of water is also formed and excreted by the lungs, skin, or kidneys.

The Kidneys.

The kidneys are deeply placed in the loins, lying one on either side of the spinal column. In the adult each is about 4 inches long, 2½ broad, and 1¼ thick, and weighs about 4 ounces. To each kidney runs a large artery, and from each a still larger vein.

The kidney consists of an immense number of tubes intricately folded, and the whole is contained within a strong fibrous capsule. Each tube begins near the surface by a blind end; into this blind

end a small artery penetrates and immediately forms a globular bunch of capillaries; it is from this bunch of capillaries that the water of the urine exudes. The next part of the tube is lined by large granular cells, which extract from the blood the urea and uric acid: these are at once dissolved by the water coming down from the globular bunch of capillaries. The cells also have the power of picking out various salts, chiefly phosphates and chlorides, from the blood, and also many poisons. The tube then makes a long loop and returns again to the surface, where it contains more large granular excreting cells; lastly, it opens into a straight tube which delivers the fluid it contains into a hollow in the substance of the kidney; from whence it is carried by a long fibrous canal to the bladder.

The kidneys are the organs that purify the blood from nitrogenous waste products, just as the lungs are the organs that purify it from the waste product of carbohydrates and fats (carbon dioxide).

Urea, the chief product of the using up of proteid food, is formed in the tissues, discharged into the blood, withdrawn from the blood by the cells of the tubes of which the kidney is formed, and finally discharged from the body in the urine.

The grosser waste products of digestion, and all indigestible constituents of food such as cellulose, gristle, etc., accumulate in the large intestine, and are finally expelled from the bowel.

FOOD.

Food is required to supply the energy necessary for the work of the body, and for the production of heat. It supplies material to make good the waste of the tissues, and material in childhood for growth.

Plants possess the power of building up the complex organic substances of which they consist, from simple inorganic bodies: water, carbon dioxide, nitrogen, ammonia, nitrates, nitrites, etc. During the process of growth in a plant, kinetic, that is to say, active, energy disappears, and is converted into potential energy, hidden or latent in the starchy and other compounds; the energy thus rendered latent in plants is derived by them from sunlight. Animals derive their food directly or indirectly from the

vegetable world; even carnivorous animals obtain it from the vegetable kingdom at second-hand, since they devour vegetable-eating animals.

Food, after being digested, is absorbed and incorporated into the tissues of the body to repair their waste. The activity of the tissues depends on oxidation, that is to say on a process of slow combustion, the final products of which are water, carbon dioxide, and nitrogenous bodies; when exposed to the air, these are transformed by microbes into ammonia, nitrates and nitrites. These simple bodies are again taken up by plants, and thus there is a complete cycle in which the vegetable world builds up more complex bodies, and the animal breaks them down again.

A complete diet must contain certain inorganic constituents (water and salts), and three classes of organic bodies: proteids, carbohydrates, and fats. The two latter classes of food are composed of carbon, hydrogen and oxygen combined in various ways; the proteids contain nitrogen in addition, and also in most instances sulphur. We may classify foods in regard to their chemical constitution as follows:

Organic	Nitrogenous	Proteids (meat, gluten, etc.). Gelatin.
	Non-nitrogenous	Carbohydrates (starch, sugar). Hydrocarbons (fats, butter, oil).
Inorganic	... ...	Water. Salts.

In estimating the value of any article of food, the following points must be taken into account:

1. Its chemical constitution.
2. Its energy-producing power.
3. Its digestibility.
4. Its cost.

In estimating the sufficiency of a diet, we must ascertain that the different classes of food are present in proper relative proportion. It is indeed possible to replace starches by fats, and *vice versâ*, to a certain extent and for a limited time; but the result is, under ordinary conditions, unsatisfactory, as we see in infants who are fed upon starchy foods and deprived of fats. A large consumption of proteids may make up for a deficiency of the other constituents,

and this is very often the case in the diet of the richer classes; this is not only extravagant in cost, but leads to a waste of energy and is injurious to health, causing gout and various digestive disorders. A diet at once wholesome and economical can only be framed by selecting foods which, when combined, contain proteids, carbohydrates and fats in due proportions. It is true that the Esquimaux live on a diet in which the non-nitrogenous food consists almost solely of fat; it yields, as will be seen, a great deal of energy needed in the Arctic climate for transformation into heat, and the digestion of the race has been adapted to the exceptional conditions.

Energy Derived from Food.

The energy-producing power of a food is estimated by ascertaining the amount of heat generated by its complete combustion. The calculation is based on the amount of the substance which must be completely burnt to raise 1 kilogramme of water 1° Centigrade; the amount of heat necessary to do this is called a Calorie. It is true that the whole of the food is not completely burnt, oxidised, in the body, but by making proper allowances, the quantity of energy actually yielded to the body by each variety of food has been calculated. For instance, proteid substances are not completely oxidised in the body; the residue is still capable of oxidation, during which it yields energy; 10 grammes of proteid when completely oxidised yield in round numbers 57 Calories; they give, however, a residue of 2·8 grammes of urea which still possesses a potential energy of 7½ Calories, so that the amount of energy actually obtained by the body from 10 grammes of proteid is $57 - 7\frac{1}{2} = 49\frac{1}{2}$ Calories. The amount of energy yielded by one gramme (dry) of the several classes of food is:

Proteids	4·8 Calories
Fats	9·8 "
Carbohydrates	4·2 "

The Energy Expended.

The energy expended by the body daily, even when no labour is performed, is very considerable. The following is an estimate for a person at rest weighing 66 kilogrammes (10½ stone):

Heat radiated from the body (clothed) ...	1,560 Calories
„ rendered latent in the evaporation of water from lungs and skin ...	599 „
Warming of expired air	80 „
„ „ water drunk	53 „
	2,292 „
Work done by heart and respiration ...	180 „
„ „ in other movements	320 „
	2,792 „

A diet yielding this amount of energy is sufficient to keep the weight of such a person constant while resting, and it will be seen how large is the amount of energy required to keep the body going, even when no work is done. The amount of energy, and therefore of food required, is increased in cold weather (to maintain the heat of the body) and by work. A man doing hard work needs a diet yielding from 4000 to 6000 Calories.

Quantity of Food: Diets.

The proper proportion of nitrogenous (proteid) foods in a diet, to the non-nitrogenous (fats and carbohydrates together) is about 1 to 3½ or 4½. The quantity of food required to maintain the body in health at a given weight, varies with the age and size of the individual, with the amount of work done, and with the climate. The following table, founded on careful experiments, shows the amount of the various classes of food required daily at various ages:

AGE.	NITROGENOUS.	FATTY.	CARBOHYDRATES.
Child up to 1½ yrs.	20 to 36 grammes	30 to 45 grammes	60 to 90 grammes.
„ 6 to 15 „	70 to 80 „	27 to 50 „	250 to 400 „
Man, moderate work	118 „	56 „	500 „
Woman „ „	92 „	44 „	400 „

Milk.

Milk, the natural food of young animals, contains the three constituents of a complete diet. Of the proteids the most characteristic is casein: this when acted upon by rennet, a ferment

present in the infant stomach, coagulates; most of the fat is entangled in the meshes of the curd, to which it gives its white colour; casein is also precipitated by acids. The carbohydrate is sugar of milk (lactose), and this remains dissolved in the whey when milk is curdled. The hydrocarbon is butter-fat; it is in a state of emulsion, and when milk is examined under the microscope globules of fat varying in size, but all minute, are seen floating in a clear fluid. Being lighter than the other constituents, the fat globules rise to the surface when milk is allowed to stand, and are skimmed off as cream to make butter; nowadays, however, milk is usually passed through a centrifugal machine (separator) which separates the cream more rapidly and more completely. So-called separated milk contains most of the proteid and milk sugar but hardly any fat, and is therefore not a suitable diet for infants.

Human milk contains in round numbers nearly two parts of nitrogenous, four of fatty, and six of carbohydrate material. More exactly, 1000 grammes ($1\frac{3}{4}$ pints) of human milk, about the quantity consumed by a healthy infant of 3 months, contains 18 grammes of proteid, 39 grammes of fat, and 62 grammes of carbohydrate (milk sugar). The energy it yields is 729 Calories.

Mixed Diet.

It has been said that an ordinary mixed diet contains nitrogenous fatty and carbohydrate substances in certain proportions. The foundation of such a diet is usually meat, butter and bread. As a rule the diet is varied by replacing more or less of the meat by fish, of the butter by fat bacon or dripping, of the bread by potatoes, rice or oatmeal. It must be recollected that all so-called solid foods contain a good deal of water; about three-fourths of the weight of mutton, of herrings and of potatoes is water; the remaining quarter in meat and herrings consists of proteid and fat; in potatoes of starch chiefly. Wheaten bread contains more than half its weight of carbohydrates, and only about one third its weight of water.

In framing a dietary, it is not sufficient to consider merely the chemical composition of the constituents, its digestibility must also be taken into account: a nourishing diet must not only be adequate in quantity, but digestible and palatable. Cheese, for example, which from its chemical constitution appears to rank high, is in

reality very indigestible. In arranging a diet we have to bear in mind also the price of the food and the proportion of waste material it contains. There is some indigestible material in all ordinary articles of diet; the bone and gristle of meat, for instance, are acted upon little, if at all, by the digestive organs of man, and the cellulose, which forms a varying and often large part of green vegetables, is quite indigestible (see below). There is on any diet a residue not utilised, but voided from the bowels. The percentage of various sorts of food passing unused from the bowels is: of rice, 4·1; of white bread, 4·5; of black bread, 15; of potatoes, 9·4; of peas, 11·8; of beans, 18·3; of meat and eggs, 5·2; of milk, 9.

Meat contains a large proportion of proteid in the muscular tissue proper, together with some gelatin derived from its connective tissue, a varying amount of fat, and a relatively large proportion of extractives (see below) and salts.

Butter consists almost entirely of fat.

Wheat contains 56 °/₀ of carbohydrates and about 17 °/₀ of proteid, of which the greater part is gluten. It contains also a large proportion of salts, the most important being the earthy phosphates necessary for the formation of bone. In the ordinary processes of milling a great deal of the gluten, most abundant just beneath the husk, is lost with the bran. The bran is given to cattle and pigs, people in most countries preferring to get their proteids from meat. This is an expensive plan, but coarse bread is apt to derange the digestive organs, whereas meat is very digestible.

Bread. Gluten, when mixed with warm water, forms a kind of sticky jelly; it gives the consistence to dough made by kneading flour with water. During kneading yeast is worked into the dough, and this is then put in a warm place to rise. The starch granules, liberated from their enclosing cellulose envelope by the process of grinding, swell up and become gelatinised in the heat and moisture, and the starch is partly transformed into sugar; at the same time the yeast, a kind of fungus consisting of single cells, multiplies rapidly. During the process of growth it consumes some of the starch, producing carbon dioxide gas; this, by forming bubbles in the dough, causes it to rise. When it has risen sufficiently, it is made into loaves and baked, the temperature of the oven solidifying the gluten. Bread owes its digestibility to its porosity, which allows

the digestive juices to penetrate easily, and to the fact that much of the starch is changed into soluble starch or sugar. Aerated bread is made by forcing air into the dough; it is porous, but the starch is not so much changed. Baking powders are mixtures of bicarbonate of soda with an acid salt; when the powder is worked up with water and flour, carbon dioxide gas is set free in the dough which is thus rendered more or less porous.

Pulses.—Peas, beans, and lentils are valuable alternative articles of diet. They contain more proteid and less starch than wheat flour, but also a good deal of cellulose, and this renders them rather indigestible.

Corn flour (made from maize) resembles wheat flour in composition, but contains more starch and less proteid.

Rice contains still more starch and less proteid, and is therefore a very imperfect substitute for bread.

Fruits and Vegetables.

Fruits, though they do not possess much nutritive value, are for other reasons valuable articles of diet. They all contain some carbohydrate, a small amount of proteid, flavouring substances, certain vegetable acids, salts, cellulose, and a great deal of water.

The carbohydrate of ripe fruit is, for the most part, a special form of sugar, lævulose, which seems to be particularly easily assimilated by man, since it can be taken by diabetics unable to assimilate ordinary sugar; there is also a small quantity of a gummy substance called pectin; this, when fruit is boiled as in making jam, sets in a jelly on cooling.

The acid present in largest quantity varies in each fruit: in apples it is malic (malum, an apple); in lemons, citric (citrus, a lemon); in grapes, tartaric, and so on. The acids are combined with potash. The amount of cellulose varies very much; there is, for instance, very little in a ripe strawberry, but a great deal in an unripe apple. It forms a kind of framework in minute compartments containing the carbohydrates; as cellulose is not affected by the digestive juices of man, an unripe apple is very indigestible. During the process of ripening in warm weather the vegetable acid in the fruit dissolves the cellulose and sets free the carbohydrate, so that a ripe apple is very easily digested. The amount of acid

diminishes during ripening and this helps to make ripe fruit more digestible than unripe.

The proportion of water in fruits is always large. It forms about nine-tenths of a strawberry, lemon, or melon ; about a fifth of grapes or plums ; oranges and apples are intermediate. Bananas possess considerable nutritive value, as more than one fifth of their weight is carbohydrate. Dried fruits, of course, contain more solid material in proportion to their weight, and the ratio of carbohydrate may even be very high—in dried figs it is 63 °/₀, in dried dates and prunes 66 °/₀.

Green vegetables contain a very small proportion of food-stuff (about nine-tenths of raw cabbage or cauliflower is water), and when boiled they lose a great part of their small stock of nutritive matter ; this consists chiefly of carbohydrate ; the amount of proteid is small, and there is little or no fat. Green vegetables contain a rather large proportion of mineral salts, chiefly potash salts, with an alkaline reaction. They help to keep the blood supplied with the alkali required by it, and are especially useful additions to a meat diet. Not easily digested either in the stomach or intestines, they are very apt to be fermented by the microbes present in the latter. They are also very imperfectly absorbed, leaving a large, solid waste residue ; this is not altogether a disadvantage, as they increase the bulk of material which reaches the large intestine, and stimulate its movements. They therefore tend to prevent constipation, apt to be produced by a diet consisting too largely of meat.

Fresh fruits and green vegetables also possess anti-scorbutic properties, of the utmost importance in diet. Scurvy, scorbutus, is a disease of the blood occurring in people who live exclusively on preserved, tinned or salted foods. It used to be a terrible scourge in the Navy, and Lord Anson, in his fascinating account of his voyage round the world, has drawn a striking picture of the shocking sufferings of his crew from scurvy. Armies, especially the garrisons of beleagured fortresses, have been ravaged by it, and it was very serious in Ireland during the great famine of 1847-8, when, owing to the failure of the potato crop, the people were deprived of their main source of fresh food. It occurs also in infants fed exclusively on tinned milk and other preserved foods,

and owing to the increased use of such foods is probably becoming more common, particularly among the infants of the class above the very poor; the poorest are less careful to keep their babies strictly from sharing the family meals. Short of actual well-marked scurvy a deficiency of fresh fruit and vegetables tends to produce poverty of blood and anæmia. Even when it has developed to a serious degree, scurvy may usually be quickly cured by adding fruit or fresh vegetables to the diet: lemons, limes, potatoes, cabbage or lettuce.

From the anatomical point of view, there is very little to be said for the doctrine that man's diet ought to be vegetarian, meaning by that, green vegetables and cereals. Neither the teeth nor the digestive organs of man bear any close resemblance to those of the herbivorous animals. They more nearly resemble those of the omnivorous, and the old anatomists who found difficulties put in the way of teaching human anatomy were, it is said, in the habit of using the organs of the pig for the purpose of instructing their pupils. The fact is that in the number and form of his teeth, and in the length and general character of his alimentary canal, man very closely resembles the fruit-eating apes, to which group he is in other respects most nearly related. Arguments founded on this are, nevertheless, weakened by the fact that in the first glimpse we get of early man we find him a hunter, living on the fruits of the chase, and strewing his caves with bones, cracked to extract the marrow.

Cost of Various Foods.

Wheaten bread, which forms the basis of most diets, is a cheap food. It provides on an average one-third of the energy, and one-third of the proteid; as an energy provider, only oatmeal and sugar, and as a proteid provider, only oatmeal and peas are cheaper.

Oatmeal is cheaper than bread, both as an energy and proteid producer. The reason oatmeal has ceased even in Scotland to be much used, is probably because it requires careful cooking to render it wholesome as a food. Undercooked oatmeal is difficult of digestion, and therefore dangerous: it should cook for at least two hours. If, however, the oatmeal is allowed to steep in cold water overnight and is boiled in the same water, in order to retain the salts, a much shorter time will suffice to cook it.

Potato is, as an energy provider twice, and as a proteid provider more than twice as expensive as bread. Its antiscorbutic properties justify its large use, it being second in quantity to bread in the diet of the labouring classes.

Other vegetables are unfortunately so little used by the British people, that the expenditure on them is a very small item in the cost of their food.

Sugar is the cheapest of energy producers, and is so largely used in the diet of the labouring classes, that it is in this respect second only to bread in importance.

Milk, as a source of energy is five times, and as a source of proteid three times as dear as bread. Its value in the diet of young children is so great, that a comparatively large family expenditure on it is justified.

Cheese, both as a proteid and as an energy provider, is a cheap food; it supplies the proteid and fat lacking in a diet consisting largely of bread and sugar.

Eggs are an expensive food, both as energy and proteid providers; they are largely used, probably because they are so easily cooked.

Beef is, as a source of proteid four times, as a source of energy nine times as dear as bread; mutton and ham are cheaper in both respects.

Fresh fish is cheaper as a proteid yielder than meat, but as an energy provider it is dearer than bread or butter; dried or smoked fish is not nearly so economical, and as a proteid provider is dearer than beef.

Butter and margarine are cheap sources of energy, though more expensive than vegetable foods. They are so generally used, that in an ordinary diet they rank after bread and sugar only as energy producers. Dripping and suet are also cheap sources of energy.

A diet of tea and bread and butter, upon which so many children are brought up, is faulty, its energy value and proteid value being both too small. The faults can be corrected by adding meat, fish, or eggs, but this is an expensive plan. A more practical way of improving the diet is to replace at least one meal of tea and bread and butter by a meal of porridge and milk; a meal of tea, sugar ($\frac{1}{2}$ oz.), milk ($1\frac{1}{4}$ ozs.), bread (10 ozs.), butter ($\frac{1}{2}$ oz.), costs about

1½d., and so does a meal of oatmeal (8 ozs.), made into porridge and taken with milk (10 ozs.) ; but the porridge and milk meal yields more proteid and fat, and more energy.

MEAL.	PROTEIDS.	FAT.	CARBOHYDRATES.	CALORIES YIELDED.
Tea. bread and butter	27½	16½	166½	950
Porridge and Milk	46	27½	167½	1133

The same end may be attained by the use of peas, beans, and lentils ; a meal of pea-soup and bread, or of beans, fat bacon and bread, need cost no more than a meal of tea, bread and butter, and would correct the faults of the latter diet.

The diet of the British people has degenerated probably because of the distaste for cooking so common among women of the labouring classes.

Food and Diseases.

Food, especially animal food, which has been kept too long becomes unwholesome, and in a state of decomposition may become so dangerous as to cause diarrhœa, vomiting, and even death. This applies to meat, sausages, fish, and fruit. As to tinned foods they are to be avoided, as being more likely to be unwholesome than fresh food ; but if, through circumstances, tinned foods have to be used, they should be consumed as quickly as possible, for once opened they decompose rapidly, the microbes in the air falling upon them and multiplying with incredible rapidity.

Meat from diseased animals is to be guarded against. In pork, a favourite dish among the labouring classes, trichinæ are sometimes present. These worms live in the muscles of the pig, and when not destroyed by thorough cooking, breed in the intestines of human beings and pass into their tissues, giving them trichinosis, a malady the symptoms of which are fever, diarrhœa, and muscular pains. This disease not infrequently ends in death. Besides this, if man eats pork or beef in which are bladder worms, he is liable to get tape worm. Eating the flesh of cows or pigs infected with the tubercle bacillus may cause tuberculosis in man, and the

milk of tuberculous cows produces the same effect. In order to check this, many cows are tried with the tuberculin test, and if they react to it ought not to be used as milkers, nor should their flesh be eaten.

Epidemics of typhoid fever and severe diarrhœa have taken place from eating oysters, cockles, and other shell fish, and when the matter has been investigated it has been found that they came from beds polluted by sewage. The same thing applies to watercress, which often grows in a stream containing foul water.

Seeing the indifferent larders in most of the habitations of the labouring classes, it is advisable to boil the milk at once when it comes into the house, to pour it into a jug, to cover it from the dust and to put it in the coolest possible place. Boiled milk has a few drawbacks, such as being less palatable and somewhat less digestible, but there are advantages to health from boiling; it keeps better, owing to the destruction of micro-organisms and ferments, and is far safer. No food is so easily contaminated as milk; a good culture medium for bacteria, outbreaks of typhoid fever, diphtheria, and other diseases have been traced to the presence of the specific bacilli in milk.

Cooking.

Cooking is not a necessity to render meat digestible, in fact, cooked beef is digested more slowly than raw scraped beef, but it brings out flavours which to man are agreeable, stimulating the appetite and the flow of the gastric juice: starchy foods, on the other hand, are very indigestible unless cooked. Cooking has the hygienic advantage that it kills many bacteria, especially those which may have fallen upon the surface and are growing there; as is well known, cooked meat will keep longer than raw. Whether bacteria in the interior of a joint of meat are killed or not depends on the temperature, and as meat is a bad conductor, the temperature attained in the centre of a joint, boiled, roasted or baked in the ordinary way, may be far below the death point of some of the disease-producing bacteria; the tubercle bacillus for instance may escape. All animal parasites (worms) are killed by ordinary cooking.

Chemistry of Cooking.

Meat.—Cooking coagulates the proteids of meat. This occurs at or below 170° F., and there is no advantage in employing a higher temperature, but rather the contrary, as it causes the proteids to shrink and become harder and less easy of digestion: re-cooking has the same effect. The aim of the cook should be to coagulate the proteids, and to do this without allowing the nutritious parts or the flavours to be lost. If meat is put into water and boiled, a great part of the flavour is extracted by the water, and much of the proteid is also extracted, coagulated and wasted. Meat should be cooked quickly at first to seal the surface by coagulating a thin layer, and so retain the juices and flavours in the interior.

It is unfortunate that the term boiling was ever applied to the cooking of meat, as it makes people think that the temperature of the piece should be raised right through to the boiling point of water; as a matter of fact, for the reason mentioned, this never happens except in the case of a very small joint. If meat is to be boiled it should be plunged at once into boiling water so as to seal the surface, and after a few minutes the cooking should be continued at a lower temperature, considerably below the boiling point of water: what is called simmering. A good example of what may be done by slow cooking is the Norwegian cooking box, which has double sides with felt or other non-conducting material between. The joint, or chicken, is put into boiling water in a pan, and kept just boiling for five or ten minutes to seal the surface; the pan is then put into the box and the lid closed tightly; without more heat the cooking of the joint goes on slowly in the box, and when it is opened in seven or eight hours or even longer, the food is found to be thoroughly cooked, tender, and steaming hot.

Proper roasting, baking, or grilling depends on the same principle of first sealing the surface, and then continuing the cooking slowly.

Animal foods become less watery by cooking; the loss of weight from this cause in beef is, when boiled, about a quarter, when roasted, about a third; mutton loses rather less than this by boiling, rather more by roasting. Cooked meat is a more concentrated form of food than raw; it loses also some of its extractives

and salts. Extractives is the term applied to the bodies, of unknown chemical composition, which give the characteristic odour and taste to meats, and are extracted and lost by boiling; by proper cooking they are transformed into substances particularly palatable to man.

The flavours of fish are slighter than those of meat, and more easily lost by bad cooking; more of the nutritive material also is lost. It is therefore advisable to fry fish. This is done by plunging it into a deep pan containing enough boiling fat or oil to cover it; as the temperature of boiling fat is about 360° F., the surface of the fish is very suddenly and completely coagulated, and the flavour and nutrient matters retained, the fish being cooked through in a few minutes. What is ordinarily called frying, where only enough fat is used to prevent the fish sticking to the pan and burning, is in reality a kind of grilling or roasting, and a much more wasteful method.

Vegetables.—Nearly all vegetables contain starch. Raw starch granules, as has been said, are not easily digested by man, and the difficulty is increased by the fact that the granules are contained in compartments formed of cellulose, which is quite indigestible by him. The effect of grinding wheat, oats, maize, etc., is to break up the cellulose compartments and set the starch granules free. Cooking does this and more; moist heat causes the starch granules to swell, they burst their cellulose envelopes and the starch itself becomes gelatinised, forming starch jelly; this happens at a temperature of about 180° F., nearly the same as that at which proteids coagulate. By boiling, vegetables take up water and lose some of the extractives which give them flavour, and also some of their salts.

It is interesting to recall that in fruits, almost the only articles of food eaten raw by man, the changes produced during the process of ripening are analogous to those produced by the cooking of, for example, a potato: the cellulose envelopes are broken up and the carbohydrates liberated.

Water.

Water is a necessity to life; it forms two-thirds by weight of the body and at least four-fifths of our food. During digestion all the different kinds of food except fat are dissolved in water, so that they

can be taken into the blood or lymph, and even fat is made into a smooth, fine mixture or emulsion. Water is the great solvent of salts, which are introduced into, and removed from, the body dissolved in it.

Water is a chemical compound of two atoms of hydrogen with one of oxygen. Between the temperatures of 0° and 100° C. (32° and 212° F.) it is a colourless, odourless and tasteless liquid. At 0° C. it freezes into ice, and at 100° boils into steam. As water so readily dissolves salts and many other substances with which it comes in contact in the soil or air, or the tanks and tubs in which it is stored, it is never found chemically pure in nature. One of the main objects of sanitation is to ensure that the substances dissolved in drinking water, or suspended in it, are not injurious. The character of the substances must obviously depend upon the source from which the water is obtained.

Sources of Water.

All water used for drinking is derived from rain. Part of the rain runs off the soil into streams flowing into lakes or rivers; another part sinks into the soil until it reaches some impermeable stratum, where it either accumulates in an underground reservoir, or flows away through cracks and fissures, to appear perhaps at some distance in a spring. From the sea, from lakes, and from the surface of moist ground water is being continually evaporated, and rises in vapour into the air, where it forms clouds and again falls to earth as rain. As the salts of the sea and the impurities of the soil or rivers do not evaporate, the vapour when it first rises from sea or land is almost absolutely pure. As it falls in rain, it dissolves gases from the atmosphere, oxygen, nitrogen, carbon dioxide gas and ammonia. It also carries down with it dust, soot, or any other matter floating in the air. Even rainwater by the time it reaches the earth is not pure, although it is less impure in the country than in towns. In the country rainwater is often collected from roofs in casks or cisterns. The first water that falls after dry weather washes the roofs; it is, in consequence, very dirty and should be rejected. There are several contrivances for rejecting it automatically. As ordinarily collected in tubs rainwater is not fit to drink, although, being very soft, it is much valued for washing. It may be made

fit to drink by filtering and boiling; drinking water is, however, usually obtained from rivers, lakes or wells.

Rivers.—River water, when it comes from mountains or other tracts of country with few or no inhabitants, is generally free from injurious impurities. But when it comes from inhabited or cultivated ground, or when a mountain river passes through villages or towns it quickly becomes contaminated, and is dangerous for drinking purposes until it has been properly filtered or boiled. When a town is supplied with river water it should be filtered before delivery; this is usually done on a large scale, by passing the water through a bed of sand and gravel in layers.

Lakes may be natural or artificial (reservoirs). The water in a natural lake is likely to be pure, inasmuch as it is usually supplied by mountain streams. Frequently the size of the lake is increased by a dam; or a lake entirely artificial is made by building a dam across a valley. The land which drains into such a lake is called the catchment area, and it is important that the water running from the catchment area should not be fouled by habitations. For this reason some great cities have purchased the whole of the valley or valleys draining into their lake reservoir. The water is carried from the lake reservoir in large pipes to a storage reservoir, generally situated on high ground close to the city. In the case of Manchester, for instance, it is piped from Thirlmere Lake in Westmoreland, seventy miles, to a storage reservoir close to Manchester. From here the water is delivered by gravitation into every house in the town.

A public water supply may become cantaminated (1) at its source; this may be prevented by insuring that the catchment area is free from possible sources of impurity: (2) in the main pipes, but this is not probable as the water is constantly under pressure; (3) in the storage reservoir, and this is avoided by strict attention to its cleanliness; (4) in the supply pipes to houses; or (5) in house cisterns.

Water may be supplied on the continuous or discontinuous system: in the continuous system the domestic supply pipes are constantly full of water under pressure, so that if any leakage occurs it is outwards, and though water is wasted the pipes do not become foul. In the discontinuous system water is only

supplied during certain hours: consequently the pipes are empty, or partly empty, during these hours, and if they leak foul matter may find its way into them from the soil. A discontinuous supply renders it necessary to have cisterns in every house: it is very important that these should be placed in an accessible position, and that they should be cleaned periodically.

A spring is a natural outflow of underground water. The water may come from the immediate neighbourhood, when the spring is called a land spring, or it may flow along the surface of an impermeable stratum from a long distance, when it is called a main spring. Such springs are commonly supplied by large underground natural reservoirs, and so usually yield a regular supply. As a rule, spring water is more or less hard. Main spring water is generally free from contamination: but a land spring, if drawn from a cultivated inhabited area, is often impure.

Wells are of two kinds, shallow and deep, the former is filled by the water as it percolates through the soil; the water in such wells is liable to be contaminated by surface impurities, leaky drains, or cesspools; epidemics of typhoid fever have been traced to such occurrences. A deep well is sunk perhaps as much as 700 or 800 feet down to an underground reservoir; if the bore is properly protected from surface contamination, the water is pure.

Mineral impurities result from the soil through which the water has to pass. The purest water is to be found in soils the geological formation of which is slate, chalk, granite and metamorphic rock or clay; limestone, or magnesium-limestone waters, though generally free from organic matter, contain the fixed hard salts, calcium sulphate, and magnesium sulphate in excess, and are therefore less safe than chalk, although chalky water unboiled is bad for persons who suffer from rheumatism.

Hard and Soft Waters.—The terms hard water and soft are applied according to the effect of the water upon soap. Soft water easily forms a lather, hard only after a varying amount of curd has been formed. The hardness is usually due to the presence of salts of lime or magnesia, more rarely of iron in the water. Yellow soap is a combination of fatty acid and soda, forming an oleate of soda; soft soap is an oleate of potash. With soft water the oleate at once forms a lather; with hard not until the soda or potash has been

replaced by the lime, magnesia or iron in the water. As the cleansing property of soap is due to its lathering, there is a great waste of soap with hard waters. Hard water also is not good for cooking: vegetables, for instance, boiled in it are hard, and, as is well known, tea does not infuse so well as in soft water. All the ordinary toilet soaps are made from yellow soap.

Doubtful Water. Where water not above suspicion has to be used, the most effectual means of purifying it is by boiling; this destroys all bacteria, although certain spores may survive. These spores can be killed by a second boiling if the water, after the first boiling, is allowed to cool slowly.

Filters. The majority of household filters are made of charcoal, and are useless, if not dangerous, for they may actually be the breeding ground of noxious bacteria. Filters in which the filtering material is unglazed china (Pasteur-Chamberland), or a porous earth (Berkefeld), if kept thoroughly clean, are effective.

Beverages.

Provided water is pure it is the most wholesome beverage in the world, and the Japanese, the healthiest and strongest nation in the world, attribute this in great measure to the large quantities of water they drink. But it is very dangerous to drink impure water and most of the filters sold to render water pure add only to its impurity: thus a charcoal filter collects the impurities, becomes slimy, and unless constantly boiled, poisons the water as it passes through. The safest method is to boil all drinking water, allowing it to get cold before drinking.

Aërated Waters.

Soda water is made by adding a few grains of sodium bicarbonate to each pint of water before its aëration with carbon dioxide gas. Lemonade and other fruit-flavoured effervescing drinks are made by putting certain proportions of the fruit syrup in the bottles before they are filled with aërated water.

Tea, Coffee and Cocoa.

Tea consists of the dried leaves of a shrub grown chiefly in India, Ceylon and China. The cheapest tea consists of the large coarse

leaves, while the buds and delicate shoots are the most expensive. In a dried condition the leaves are black, owing to having been allowed to lie in damp heaps for several hours to undergo a process of fermentation before being dried slowly over charcoal fires.

When analysed, the ordinary percentage composition of the tea leaf is as follows: Water, 8; theine, 2·6; tannin, 14; oily matter, 0·4; starch and gum, 15; insoluble organic matter, 54; salts (of potash, iron, silica, alumina and magnesia), 6. Theine is the alkaloid to which tea owes its refreshing and stimulating properties. In moderate quantities tea is probably the most harmless of all stimulants, but it must be remembered that it has no nourishing power, and that any nourishment which this beverage, as it is commonly drunk in England, contains is due to the added milk and sugar.

Tea, properly made and drunk in moderation, is a refreshing and stimulating beverage. Taken in excess and improperly made it is dangerous to health, causing indigestion, anæmia, constipation, insomnia and nervousness. The aim in making tea should be to extract all the theine and as little of the tannin as possible. A moderate amount of tea leaves should be put into a tea-pot, boiling water poured upon them, and the mixture allowed to stand only three or four minutes before being poured out and drunk with milk and with, or without, sugar. Improperly made tea is brewed in the same way but allowed to stand and stew for hours on the hob or in an oven, water being added from time to time. Such tea has much the effect that slow poison would have if taken continually, because the stewing process extracts the tannin, the element that interferes with digestion. Tannin is the material used to tan skins into leather; it has a similar hardening effect upon food, and a very astringent one upon the mucous membrane. Stewed tea would be a good astringent gargle for sore throat, but it is not wise to apply an astringent lotion to the mucous membrane of the stomach.

Coffee is the berry of a shrub cultivated in Ceylon, the West Indies and other parts of the tropics. It is necessary to roast and grind the berries before they can be used. The percentage composition of unroasted coffee is: water, 11·23; nitrogenous matter, 12; caffeine, 1·3; fat or oil, 12·25; sugar or dextrin, 8·55; tannin, 32·8; cellulose, 18·16; salts, 3·7; its principal properties are due to the alkaloid

caffeine and to an aromatic oil. Caffeine in coffee represents exactly the theine in tea. During the process of roasting and grinding, the caffeine becomes separated from the tannin, and the sugar and dextrin are turned into caramel, the gas and water contained in the berries being got rid of. Coffee stimulates the nervous and muscular systems, acts upon the bowels and increases the flow of urine; it is taken with more milk, and is relatively a less harmful nerve stimulant than tea.

Cocoa is the seed of a tree grown in the West Indies. The percentage composition of cocoa seeds is: water, 6; cellulose, 21; starch, 10; theobromine, 1·5; fat or oil, 50; gum, 8; salts, 3·5. The seeds are used in several manners: cocoa nibs, the seeds broken up roughly; flake cocoa, the seeds ground into a powder; soluble cocoa, the seeds from which the cellulose has been extracted. Prepared cocoa is the preparation made from the seeds; about half of the oil or fat contained in it has been extracted and starch or sugar added. The peculiar value of cocoa lies in the alkaloid theobromine which resembles theine and caffeine. As an article of food, cocoa differs essentially from tea or coffee, for the infusion of those substances is used, leaving the greater part of their bulk unconsumed, while the whole of the cocoa is dissolved and drunk. This is why cocoa is nourishing, while tea and coffee can only be regarded as stimulating.

Chocolate is really composed of cocoa, made up into cakes after much of the fat has been extracted. In pure chocolate nothing is added to the cocoa but sugar and a flavouring essence, generally vanilla; in cheaper chocolate starchy substances are added.

Alcoholic Beverages.

All beers, wines and spirits contain ethylic alcohol; the variation in their strength is due to differences in the relative proportion of water and alcohol; spirits, for instance, contain much more ethylic alcohol than beer. It is the ethylic alcohol which produces the symptoms of drunkenness common to all kinds of alcoholic beverages. The difference in flavour is due to the presence of various other alcohols, ethers, and extractives present in the material from which the beverages are made, as in the case of wine and whisky, or added to the ethyl alcohol, as in the case of gin.

Pure beer is made from malt and hops, and its flavour is due partly to the natural extractives of the malt, partly to the hops added during the process of brewing.

Malting.—The grains are moistened and kept in a warm place which causes them to germinate. During the process of germination the starch of the grain is converted into sugar; at the proper time the germinated barley, now called malt, is heated in a kiln to stop germination.

Fermentation.—The malt is mixed with water and fermented with yeast, which converts a large part of the sugar into alcohol. The proportion of alcohol in beer varies very much. In light German and English beers it may be as low as 2 or 3 per cent., while in the stronger brands of English and German beer it may be as high as 10 per cent. The colour and heaviness of a beer has nothing to do with its alcoholic strength; a cheap, turbid beer, such as that commonly sold at fourpence a quart, contains much less alcohol than clear Burton or Pilsener beer, often thought to be very little intoxicating. The body of beer is due to the unfermented sugar, dextrin, and gummy substances.

Wine is made by fermenting grape juice which contains much sugar. The amount of alcohol in natural or unfortified wine depends upon the amount of sugar in the grape juice, and the extent to which fermentation is allowed to proceed. It varies from 6 or 7 per cent., or less, of alcohol, to 12 or 14 per cent. Port and sherry being fortified by the addition of brandy, or crude spirit, contain a much higher percentage of alcohol.

Genuine *brandy* is the alcohol of wine obtained by distillation, and contains various ethers and allied volatile bodies to which its medicinal properties are mainly due. Very little of the brandy commonly sold is made from wine; it is manufactured from grain or potato spirit, to which various flavouring substances are added to imitate the appearance and taste of genuine brandy. It usually contains from 46 to 55 per cent. of alcohol, volume in volume.

Gin in England is usually made from malted barley, flavoured with juniper berries, orange peel, oil of turpentine and other essences. It contains from 50 to 60 per cent. of alcohol, volume in volume. Gin acts as a direct stimulant to the kidneys.

Whisky.—In the manufacture of whisky, barley is malted and

fermented, and the fermented liquor is then placed in a still and heated. The alcohol and various flavouring ethers are given off and condensed in the worm of the still; this process may have to be repeated once or twice. Very little of the whisky actually sold is made in this, the original way; all kinds of inferior materials are employed, and the resulting spirit often contains other substances besides ethylic alcohol injurious to the nervous system and other organs. Whisky usually contains from 40 to 50 per cent. of alcohol, volume in volume.

Pathological Effects of Alcohol.

Man has an instinctive dislike to alcohol and has to overcome this natural repugnance before he can take it for pleasure. Every child turns with disgust from stimulants, when forced by well-intentioned parents to take wine or beer as a tonic. Once this distaste has been overcome, the craving for alcohol may follow: this craving is really pathological and indicates that the nerve cells which have begun to be weakened by drink require stimulation.

Alcohol is a poison; alcoholism as deadly a habit as that of opium eating or morphinomania. Alcohol is to the human being what the whip is to the quadruped; it causes a passing stimulus and a temporary acceleration of physiological activity, after which there is reaction. The reaction causes depression with a renewed craving for stimulant; this is why the habit of drink grows and becomes a rooted vice. Alcohol is only useful for occasional sudden emergencies which are not prolonged; when long endurance is necessary it only acts as a depressant.

A great deal of the beer and spirits sold are not properly made, and this adds to the evil effects of their consumption; instead of barley, potatoes and maize, not always of the best quality, and in fact any substance containing starch is used. This is converted into glucose by treatment with sulphuric acid. It was in this way that the outbreak of arsenical poisoning occurred in the North of England in 1902. The sulphuric acid used for converting the starch contained arsenic, which found its way into the glucose and finally into the beer. There is reason to believe that this is not the only instance of this kind of poisoning.

The organs injured by the abuse of alcohol are the stomach, the

intestines, the liver, the blood, the circulation, the respiration, the vaso-motor nerves, the excretory organs, and the nervous system. The worse the quality of the alcohol the more injurious are its effects.

The Stomach.—Alcohol injuriously affects the organs of digestion and hinders the functions of the stomach, retarding peptonisation, and the digestion, absorption and assimilation of foods.

The Intestines.—That portion of the alcohol not absorbed by the stomach passes into the intestines, where it has the effect of hastening the passage of food before it is sufficiently digested and assimilated, even causing diarrhœa. The proper working of the intestines depends upon the functioning of the liver and pancreas, and these organs are adversely affected by alcohol.

The Liver.—Alcohol injures the substance of the cells of the liver and impairs their functions. The vitality of the cells is injured, and if drinking is habitual and excessive they become paralysed.

The Blood.—Alcohol enters the body by the gastric and respiratory channels: while the blood contains alcohol the emulsified fat proceeding from the chyle is not burnt, nor is the sugar. It takes twenty-three hours to free the blood from a dose of alcohol $\frac{1}{25}$ its volume. During the first hours the proportion of alcohol in the blood is very large, and the poisoning of the tissues accounts for the long period of stupor which accompanies hard drinking. Large doses precipitate the hæmoglobine, kill the red corpuscles in the blood and cause rapid death. In smaller doses alcohol absorbs part of the oxygen meant for the red globules of the blood, and lowers the body temperature.

The Vaso-Motor Centres are affected and the vessels of the skin become dilated. This causes a temporary feeling of warmth, but in reality the loss of heat is great, and the power of the body to resist the effects of exposure to cold diminished.

The Respiration is quickened by medium doses of alcohol while remaining regular, but after a time the breathing usually becomes very slow: the greater the degree of drunkenness, the slower the respiration and the lower the temperature.

The Circulation.—Small doses of alcohol increase the blood pressure, and the pulse becomes slightly slower; large doses diminish arterial pressure and the pulse becomes very slow. The heart beats less fast and the force of its contractions is lessened.

The Nervous System.—While appearing to stimulate, alcohol is in reality a depressant: it is a poison to the protoplasm of the nervous system. The functions of the higher centres are suspended and cease to control those of the second and lowest levels: hence the symptoms of stupor, weakness of the legs, unsteady gait, trembling hands, which are the sequel of drink. Alcohol does not increase muscular strength, but on the contrary lessens it, and by diminishing the rapidity and precision of nervous co-ordination, interferes with the performance of feats of strength or agility. It also diminishes the power to endure fatigue and exposure. Will power and the intellectual force which dominates and binds ideas together is enfeebled: the judgment and reasoning powers are destroyed.

Social and Moral Aspects of Alcoholism.

The prevailing idea among the labouring classes who drink is that it increases bodily warmth, supplies the place of food, removes depression and increases the working powers of the brain and body.

It has been pointed out that alcohol lowers the bodily temperature: its effect upon the muscular system is to decrease the power for sustained work and to lessen the power to control delicate movements: its effect upon the brain is to dull the functions of thought and perception and make the intellect less clear and quick. Depression is only temporarily removed, to return with greater intensity after the effects of the dose have worn off.

Alcohol not only does not supply the place of food, but it hinders the functions of the stomach and retards digestion.

Poverty and drink are closely allied. The appalling amount spent on drink, out of all proportion to the wages of the labouring classes, is cause that whole families are crippled in means and have to deny themselves a sufficiency of food and clothes.

A careful estimate of the sum spent on drink by working-class families throughout the United Kingdom shows that 6*s.* 10*d.* is the average weekly sum spent by each family. Of course very many spend much less than this, and a large number considerably more. The money is as completely thrown away as if it were flung into the sea, besides leading to deterioration of mind and body.

Drink leads to crime and insanity, and has an injurious effect upon the physique of the children of parents who are inebriates. It

is a common practice for expectant mothers and nursing mothers to take stimulants, and in both cases the children suffer. Alcohol consumed by the mother passes, as alcohol, into the circulation of the unborn child and causes all sorts or moral and physical malformations. Hereditary drunkenness may cause epilepsy, imbecility, and finally extinction: fifty-six per cent. of the offspring of inebriate women die at birth or before the age of two years, while in the case of sober women the percentage is only twenty-six.

A common cause of drink is badly cooked food. Ignorance in cooking is responsible in nine cases out of ten for the craving for alcohol; the money spent on drink might be spent on food, which, if chosen with judgment and nicely cooked, would not only build up the body, but would soon kill all unwholesome craving for drink.

The tendency hitherto has been to preach on the moral degradation of drink and to leave the people in ignorance of the physiological and economic aspect of the question. It should be clearly explained to the elder boys and girls in elementary schools that alcohol is a poison which ruins the health: that the best way to ward off the craving for drink is to have sufficient appetising and nourishing food to eat, and in order to ensure this, they must learn the properties of food and how to cook it properly. It should be pointed out to them that badly cooked meals, not infrequently bought ready-cooked at the nearest fried fish shop, send the husband to the public-house when he would otherwise be glad to stay at home: and once habits are formed they are seldom given up.

Smoking is another bad habit which interferes with the appetite and impairs the bodily activity; it is, in addition, an expensive habit. It is particularly bad for young boys, for it stops their growth and injures the nerves. This should be pointed out to them by teachers.

VI.—THE NERVOUS SYSTEM.

The Brain—General Form—The Hemispheres—The Cortex—The Mid-Brain—The Highest, Middle and Lower Levels of Nervous Action—Automatic Movements—The Spinal Cord—Nerve Fibres and Nerves—Spinal Reflex Action—The Bulb—The Cranial Nerves—The Blood Supply of the Brain and Spinal Cord—The Cerebro-Spinal Fluid—Cortical Centres, Motor and Sensory—The Growth of the Nervous System—Co-ordination and Education—The Sympathetic Nervous System.

The nervous system consists of the brain, spinal cord and nerves, by which we feel and will and move, and a secondary dependent system, the sympathetic system, by which the action of the internal organs is regulated.

The central nervous system consists of the brain, the spinal cord and the bulb by which they are connected.

THE BRAIN.

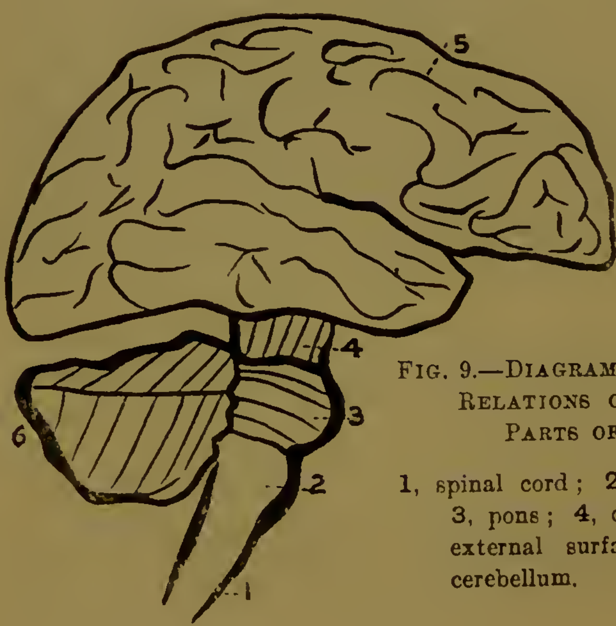


FIG. 9.—DIAGRAM TO ILLUSTRATE THE RELATIONS OF THE SEVERAL PARTS OF THE BRAIN.

1, spinal cord; 2, medulla oblongata; 3, pons; 4, cerebral peduncles; 5, external surface of cerebrum; 6, cerebellum.

The brain, consisting of the brain proper or cerebrum, the cerebellum or little brain, and the parts which connect them with each other and with the bulb (Fig. 9), is contained in the skull.

The cerebrum is divided into two equal hemispheres, right and left, upon which the vault of the skull is, as it were, moulded. The other parts of the brain lie below the hemispheres, on the base of the skull. Each hemisphere is longer than it is broad, and narrower in front than behind; their surface is thrown into many intricate folds, called convolutions. They are the seat of the highest

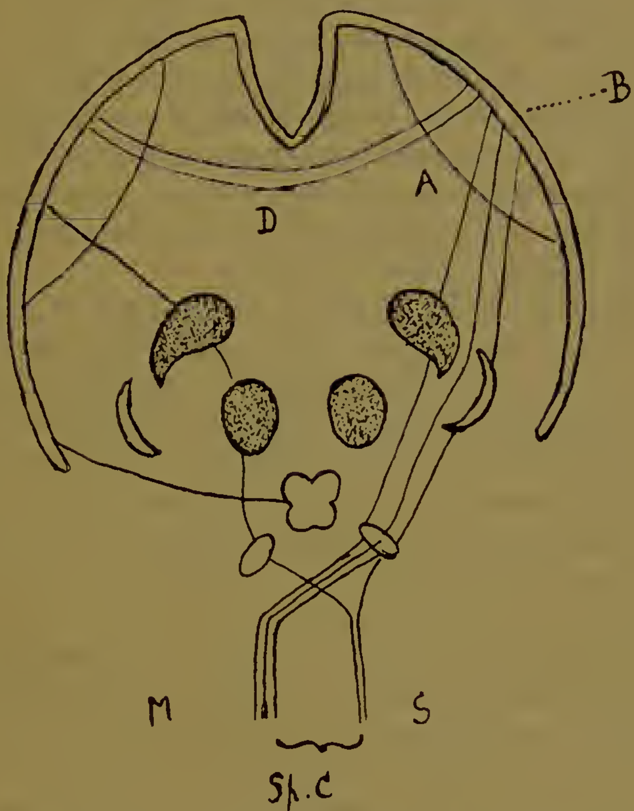


FIG. 10. DIAGRAM TO SHOW THE COURSE OF NERVE FIBRES FROM THE SPINAL CORD THROUGH THE BASAL GANGLIA TO THE CORTEX OF THE BRAIN.

S, sensory fibres passing upwards from the spinal cord; M, motor fibres passing downwards near or through the basal ganglia and crossing in the medulla oblongata before entering the spinal cord; B, cerebral cortex; A, fibres connecting different parts of the cortex on the same side; D, fibres passing from the cortex on one side to that on the other.

functions, thinking, feeling and volition, and from them start the impulses by which voluntary movements are made.

The surface of the hemispheres has a grey layer about $\frac{1}{10}$-in. thick; the rest of its substance is white with certain masses of grey matter at the lower part (base). It is in the grey layer at the surface, called the cortex (rind) of the brain that the highest functions reside. The area of the grey matter is increased by the convolution of the surface; as we descend the scale of vertebrate animals, the hemispheres are found to become smaller and their convolutions on the whole simpler. The intelligence of an animal corresponds roughly with the size of the hemispheres of its brain in proportion to the rest of its body, and the degree of their convolution.

The grey matter of the cortex is receptive and originating; the white matter below consists of innumerable conducting fibres, some passing from one convolution to another, some from one hemisphere to the other, others descending through the base of the brain into the bulb and spinal cord (Fig. 10).

The two hemispheres are connected at their under part by a broad horizontal band of white matter called the great commissure, consisting of the nerve fibres passing from the one to the other. They are connected with the bulb by two thick round columns of white matter which come out from the under surface and unite to form the single column of the bulb. Between the hemispheres and the bulb they are crossed by, and embedded in, the bridge (pons) which connects the two sides, right and left, of the cerebellum.

Embedded in the white substance towards the base of the brain are some large collections of grey matter, the basal ganglia, which may be conveniently spoken of collectively as the midbrain. In considering the mode of action of the cerebro-spinal nervous system as a whole, three planes or levels of action are to be distinguished. The highest level, that of consciousness is dependent on a healthy and perfect state of the cortex of the brain. If the activity of the cortex is suspended or destroyed unconsciousness ensues, and the will can no longer be exercised. This is the condition during sound sleep, and in this state a person may still perform acts which are apparently purposive or willed, but which are in reality below the level of consciousness. This is the second plane or level of action. Such movements occur in everybody, but are particularly easy to

observe in young children. A good example is turning over in bed, a complicated movement calling into combined or co-ordinated action a great number of muscles.

It can need no elaborate argument to convince the reader that there must be somewhere a set of very perfectly organised nervous centres in which these movements are co-ordinated. Further, if we ask ourselves why the child during sleep has turned over in bed we cannot answer that it is because it has wished to do so; consciousness and the will are suspended. We are, nevertheless, compelled to conclude that the nervous centres of the second level have in some way received impulses sufficiently strong to put them into action. There can be no doubt that such impulses come to them from the sensory nerves, especially those of the skin. These nerves pressed upon by the weight of the body perhaps for several hours, are at last sufficiently irritated to send impulses upwards, and when these become strong enough the attitude of the body is changed and the pressure relieved. A child will also, while asleep and without regaining consciousness, turn away from a light. The nervous centres of the second level, therefore, must receive fibres from the nerves of special sense. Further, they must send out nerves to conduct motor impulses directly or indirectly to the muscles; finally they must possess an arrangement by which the sensory impulses they receive are, as it were, interpreted or translated into action, and the arrangement must be complex because the resulting movements call for the co-ordinated combined action of many groups of muscles.

It is believed on good grounds that the centres of the second level are the large masses of grey matter at the base of the brain which have been spoken of as the midbrain. A very striking example of the perfection of action possible at this level is afforded by sleep-walking. A somnambulist walks and performs other actions which appear to be conscious and willed, yet we know that the will, conscious sensation, and perception are suspended. The actions performed in this state may even be more perfectly adjusted and accurate than when consciousness is active. A somnambulist has been seen to walk quite firmly and steadily along the top of a wall, wake up at the end, and be too paralysed by fear even to attempt to walk back. In certain stages of hypnotism there is a very

similar condition, the activity of the highest centres is suspended, and elaborate actions are performed under the control of the centres of the second level.

If the significance of the explanation just given is fully grasped, it will readily be understood that the actions so far mentioned do not by any means comprise all those in which we may assume the middle level centres to be chiefly concerned. There are many elaborate actions performed during waking hours which are either actually below the level of consciousness or almost completely submerged. A movement may be started consciously by the will, and continued for some time while the highest centres are occupied about something else. Walking may be taken as an example; we will to walk home along a well-known road, and on the way the mind may be actively engaged in thinking out a problem or a difficulty; it must be within the experience of everyone to have accomplished such a walk, and to find that all that remains in the memory is a recollection of the thoughts by the way and not of the road itself or the corners turned. The co-ordination or combination of movements required for walking has, by long practice, been so thoroughly organised that the act of walking is performed without the conscious participation of the will; further, in the case supposed, impressions from the eyes and other organs of sense have been received and interpreted by the centres of the second level without distinctly emerging into consciousness. The same principle can be extended to many other movements. The first time a new physical exercise is done, the will must be vigorously exerted and the attention concentrated on the series of movements to be formed. Each time the exercise is repeated it becomes easier; this means that the attention need not be so close. The explanation is that the repetition has educated the lower levels, so that they are able to time the movements and to co-ordinate them with little or no assistance from the highest centres. This process of education has gone on both in the second level which has just been discussed, and also in the third and lowest level which will now be dealt with.

The Spinal Cord.

The third or lowest level is in the grey matter of the bulb and spinal cord. Certain functions of the body calling for the activity of

voluntary nerves and muscles can yet be carried on efficiently quite below the level of consciousness. Respiration is an example, and we must even recognise that it is performed more efficiently and regularly when consciousness does not interfere. Again, there are certain movements called reflex, which occur so quickly in response to a stimulus, that the highest centres cannot have had time to act. If the sole of the foot is tickled the leg is drawn up quickly and involuntarily. Such a movement is called reflex, because the sensory impression from the sole of the foot is, as it were, reflected in the cord and translated into movement.

The spinal cord (medulla spinalis) is contained in the spinal canal and gives off nerves to the trunk and limbs. It extends from the first vertebra of the neck to the upper part of the loin where it ends, the rest of the spinal canal being occupied by the lower spinal nerves.

The cord is a firm, nearly circular rod, almost completely divided into a right and left half by deep narrow grooves back and front. In the middle of the back its diameter is about one-third of an inch; in the neck, where the great nerves for the upper limbs come off, it is thicker, its diameter being rather more than half an inch. This is known as the cervical enlargement. Near its lower end it enlarges again; this is the lumbar enlargement, and from it the nerves for the lower limbs come off; here its diameter is about half an inch.

The cord, which does not nearly fill the spinal canal, is loosely enclosed in a strong sheath of fibrous tissue, the dura mater, lined by a delicate membrane called the arachnoid, from ἀραχνη, a spider's web. The surface of the cord itself is covered by a thin membrane called the pia mater, containing many blood vessels. Between the sheath or dura mater and the pia mater is a space filled by the cerebro-spinal fluid. The cord is thus, as it were, suspended in this fluid, an arrangement which protects it from shocks and jars; it is tethered partly by the roots of the spinal nerves, partly by a delicate ligament on each side which connects it with the sheath.

The spinal cord gives off thirty-one pairs of spinal nerves which pass out of the spinal canal—eight in the neck, twelve in the back, five in the loins, and the remainder through the sacrum and coccyx. Each nerve arises from the cord by two roots, anterior and posterior, and these join as they leave the spine. The anterior root contains

the motor nerves; the posterior, which is thicker and has an enlargement (ganglion), contains the sensory nerves.

The spinal cord consists of white matter outside, and of grey matter inside. The grey matter is arranged in an irregular mass on either side and the two sides of the cord are in all parts exactly symmetrical. In a transverse section the grey matter shows as an irregular crescent on either side, extending across the middle line, forming a widespreading H. The anterior horn of the crescent is thick and broad, and from it the motor nerves arise: the posterior horn is longer and thinner, and is entered by the sensory nerves. The grey matter consists of nerve cells and the processes and nerve fibres originating from them, or going to them.

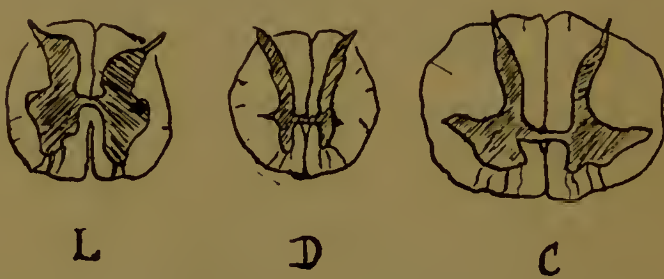


FIG. 11.—TRANSVERSE SECTIONS OF SPINAL CORD AT THREE LEVELS.

L, lumbar enlargement; D, mid-dorsal region; C, cervical enlargement.

The white matter is made up of sheathed white fibres which run in the length of the cord. They connect the cord with the brain or the brain with the cord, or different parts of the cord with each other (reflex connections). The fibres with various functions are collected in separate parts of the white matter forming the so-called colums or tracts of the cord; there are, for example, two tracts on each side, which connect the grey matter of the convolutions of the brain with the grey matter of the anterior (motor) horn and carry the motor impulses.

THE NERVES.

Every fibre of a nerve is connected with, or, it would be more proper to say, derived from a nerve cell which, like other cells, has a nucleus. The nerve cell governs the life of the fibre; if the cell is destroyed, the fibre degenerates and becomes useless. It degenerates

equally if it is cut through, and so separated from the cell. The fibre may be looked upon as a very long process from the cell, and in reality a part of the cell. At a variable distance from the cell the nerve fibre becomes covered by a soft protective sheath and is known as the axis cylinder. The sheath which contains much fat is believed to supply nutriment to the axis cylinder. When a nerve fibre leaves the nervous centre, for instance the spinal cord, with other fibres similarly sheathed going in the same direction, it is gathered with them by strands of connective tissue into a bundle which is a nerve. A nerve to the naked eye looks like a thin, smooth, white cord; the large nerves are made up of many smaller nerves.

FIG. 12.—DIAGRAM OF NERVE CELL.

A, Axis cylinder; D, dendrites.

The nervous impulses travel along the fibres, in some nerves inwards, towards the central nervous system, in others outwards, away from it. The nerves in which the impulses travel inwards are those which come from the organs of sense, from the skin (touch, sensations of pain, of heat and of cold), from the eye, from the ear, from the nose, or from the mouth (taste). They are, therefore, called sensory nerves. The nerves in which the impulses travel outwards from the nervous centres go to the muscles, and the impulses which travel along them cause the muscles to contract. They are, therefore, called motor nerves. A nerve cell, in addition to the main fibre already described, possesses also a number of extremely fine branching processes, called dendrites, which spread out from it in the substance of the nervous centre (spinal cord or brain), and interlace with similar fibres from other cells. We

may regard the cell as a kind of receiving and forwarding station. In the case of a cell connected with a sensory nerve, the cell receives impressions by the main fibre from the sense organ, and forwards them through its fine branches to the fine branches of other cells. These other cells may have main fibres so arranged that the impression is carried over to the motor side, causing a movement called sometimes an instinctive movement, but more properly a reflex movement, because the impression received from the sense organ is immediately reflected to the motor side, and causes a movement without the intervention of consciousness (Fig. 13).

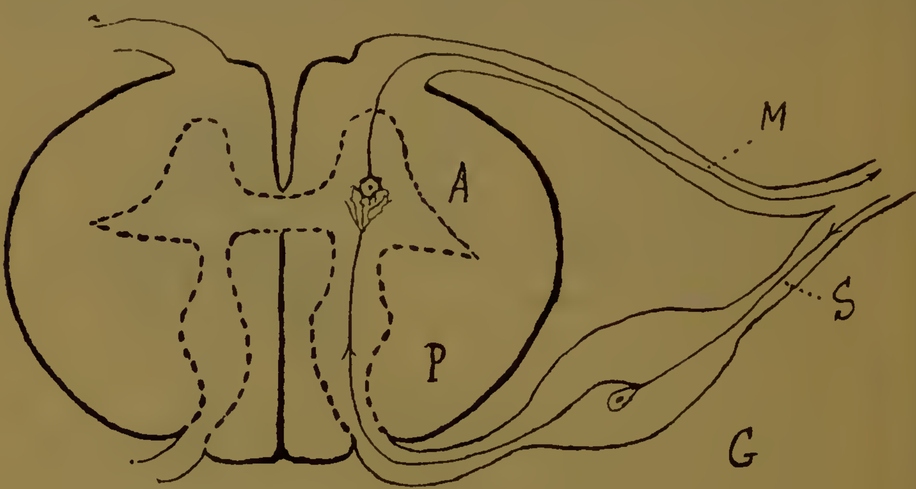


FIG. 13.—DIAGRAM OF REFLEX ARC IN THE SPINAL CORD.

S, sensory nerve fibre passing through the ganglion (G) and posterior horn (P) to enter into relations with a motor cell in the anterior horn (A); M. motor fibre.

An instance of such a reflex movement is a sudden involuntary withdrawal of the hand if the finger is accidentally pricked. We are conscious that the hand is withdrawn because the impression, besides going direct to the motor side of the spinal cord, is also transmitted to the brain, but the movement takes place before consciousness has time to be aroused to act. The reflex withdrawal may even take place against consciousness, as it were, when we know that the prick is going to be made, and have determined not to flinch.

THE BULB.

The bulb, medulla oblongata, which connects the spinal cord with the brain, is really a continuation of the former, and it resembles it generally in structure. It lies entirely inside the skull, beneath the hemispheres and in front of the cerebellum. It is, as its Latin name denotes, an irregular oblong body about an inch long, rather less than three-quarters of an inch thick from back to front, and is traversed by nerve fibres, which make up the greater part of its bulk. They are mainly those that connect the brain proper with the cord, but some end in the medulla, and others are derived from the cerebellum. Nearly all the nerve fibres carrying motor impulses from the cortex, cross in the bulb from one side to the other, so that the left hemisphere governs the muscles on the right side of the body, and the right hemisphere those on the left. The bulb contains a number of important nerve centres absolutely essential to life: death is produced more rapidly by injury to certain parts of the bulb than in any other way.

The respiratory centre, the mode of action of which has been described in the section on respiration, is double, consisting of an inspiratory and an expiratory part. It can act automatically, that is to say, it is stimulated if the blood reaching it has too low a proportion of oxygen. The cardiac and vaso-motor centres have been referred to in the section on circulation. The bulb also contains centres for sucking, chewing and the secretion of saliva, centres for regulating the pupil, for the winking of the eyelids, and for the muscles of the larynx. In the bulb also are the nerve centres of most of the twelve pairs of cranial nerves, so called because they originate within the cranium. They pass through apertures of the skull, and with one exception supply parts of the head and face. The exception is the vagus nerve; this, as is stated elsewhere, goes to the lungs, heart, stomach, intestines and spleen; it gives also sensory branches to the mucous membrane of the larynx and motor to its muscles.

Of the other pairs of cranial nerves, four, the olfactory nerve, the optic, the auditory, and the glossopharyngeal, are referred to in the articles on smell, sight, hearing and taste respectively.

Three other pairs are the motor nerves of the muscles, by which the eyes are moved; another pair supplies the muscles of the tongue,

another the muscles of the face, and another, the sterno-mastoid and trapezius muscles, which have a large share in the movements of the head. The remaining nerve is a mixed nerve, containing motor fibres for the muscles of mastication, and sensory for the skin of the greater part of the face, for the eyelids and conjunctiva.

Blood Supply and Cerebro-Spinal Fluid.

The blood supply of the brain and spinal cord is copious, and in addition to arteries and veins, it possesses a special drainage system containing the cerebro-spinal fluid. There are very numerous arteries in the pia mater, the thin membrane that closely covers the brain and spinal cord; branches from them enter the nervous tissue. The veins returning the blood from the brain are large; many of them are channels in the stout membrane called dura mater, by which the inside of the skull is lined. Others collect the blood from the walls of the ventricles, about to be described, in the interior of the brain.

The dura mater is lined by a delicate arachnoid membrane, as in the case of the cord. Between this membrane and the pia mater is the subarachnoid space, always full of cerebro-spinal fluid. In the hemisperes of the brain are two cavities, the lateral ventricles, one on either side. In them is a loose membrane, consisting almost entirely of a network of blood-vessels covered by epithelium. The cerebro-spinal fluid is secreted by this epithelium, it drains away through two other ventricles in the middle line, the third and fourth, into the sub-arachnoid space, which communicates freely with a similar space between the sheath and the pia mater of the cord. In the skull the cerebro-spinal fluid acts as a water cushion, supporting the brain evenly and protecting it from shocks. The brain varies slightly in bulk, according to the activity of the circulation through it, and as the skull is a closed cavity some provision must exist for compensating these changes in bulk, otherwise the venous circulation would be impeded. This provision exists in the cerebro-spinal fluid, which is more rapidly secreted when the brain shrinks. The fluid consists of almost pure water: it contains a trace of sugar, and of another substance, choline, produced by the using up or disintegration of the nervous substance, which is, to a small extent, the consequence of brain action. Choline is probably one of the most

important of the substances causing the sensation of nervous fatigue.

The Cortical Centres.

While it is safe to assert that the highest functions of thought, feeling, and volition are exercised through the cortex of the hemispheres of the brain, popular speakers and writers about the mode of action of the brain, often indulge in wild guesswork and assign, with great apparent confidence, different functions to all the different parts of the cortex. Men who have given a lifetime to the study of the brain, are the most ready to admit that what is certainly known is but little compared with what remains to be learnt.

Definite knowledge is almost limited to the fact that certain regions of the cortex are associated with the movements of the limbs and head, and certain others with the senses of smell, sight, hearing, and touch.

The regions of the cortex associated with movements are called the *motor centres*. Irritation of one of these centres causes a movement in the limb to which it is related; its destruction, paralysis. The paralysis does not necessarily affect a whole limb, and it is loss of power to perform a particular movement, not paralysis of a particular muscle or even of a particular group of muscles. Moreover, destruction of one of these motor centres, while it causes loss of voluntary power to make the movement, does not prevent its execution reflexly through the spinal cord. The probability is that the will acts in or through the motor centre, that an impulse starting from there is carried down to the proper sub-centre in the grey matter of the spinal cord, and that the co-ordination of the nerves which must act to produce the movement, takes place in the sub-centre in the cord.

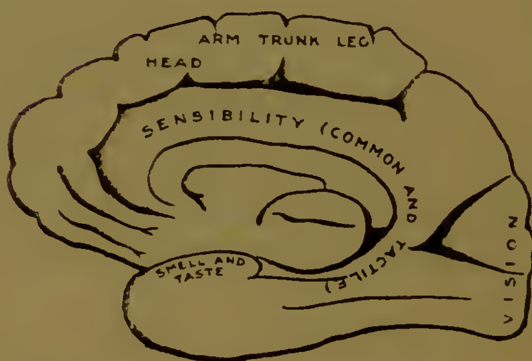
The accompanying diagram shows the position of the cortical motor centres on the outer and inner aspects of one hemisphere, the left. There are corresponding centres in the right hemisphere. Owing to the crossing in the bulb of the nerve tracts from these centres, the left hemisphere governs the movements of the right side, and vice versâ.

Conscious perception takes place in certain other areas in the cortex. Destruction of one of these cortical sense centres abolishes conscious perception through the sense organ in question. Their

position is shown in the diagrams. The centre for vision is the back part, on both the outer and inner aspects; in front of vision, on the outer aspect, is the centre for hearing, on the inner that for smell and taste. The centre for touch is in the large convolution on the inner aspect of the hemisphere curving round the great commissure.

Fig. 14.—Diagram of the Localisation of Function in the Cortex.

External aspect.



Internal aspect.

The cortical centres, both motor and sensory, are as a rule symmetrical, that is to say, there are corresponding centres in the two hemispheres. There is one very striking exception, which is very instructive, and the more interesting because it was the first centre recognised as such. Many years ago the French physician Broca discovered that disease of a small area of the front part of the brain, just in front of the area marked "lips and tongue" in the diagram,

caused loss of speech. An object could be recognised, an idea could be formed, but the name of the object could not be found, the proper word to express the idea could not be produced. The imperfection was not in the lips or tongue or larynx; words could be uttered, but they were wrong words inappropriate to the idea in the mind. Waller has put very well the steps by which a rational answer to a question is given: (1) the individual must hear or see a word or words; (2) the word heard or seen must excite an appropriate sensory idea; (3) the sensory idea must give rise to a consequent motor idea, *i.e.*, a word or words; (4) the word must be spoken; the nervous apparatus for (1), (2), and (4) may be perfect, but if (3) has broken down, the word wanted to express the idea cannot be found; it can neither be spoken nor written. We must suppose that a similar process goes on when other impressions or ideas are transformed into action: (1) a sensory impression must be received or wish formed, for example, I see a pen lying on the table; (2) this impression excites a sensory idea of using the pen; (3) the sensory idea gives rise to the motor idea of picking the pen up; (4) the motor idea finds expression in the putting out of the hand to pick up the pen.

The Growth of the Nervous System.

It has seemed well to insist on this because it will help a teacher to comprehend the structural changes that take place in the nervous system during the process of growth and education. The nervous system of an infant at birth is imperfectly developed; its brain is very large in proportion to the trunk and limbs. This is due to the fact that the human brain is born with great potentialities. It contains as many nerve cells as the adult brain, two thousand million, it is said, but a large proportion of them, probably about half, are undeveloped. A nerve cell, as has already been explained, usually has one main fibre which becomes sheathed, and in addition a number, sometimes a very large number, of branching processes through which it comes into relation with other nerve cells (Fig. 12). In the infant's brain the branching processes, and even the main fibre, may be unformed or imperfectly developed. The great tract of motor fibres, referred to above in the description of the spinal cord, as passing downwards from the grey matter of the convolutions of the

brain, motor centres, to the grey matter of the anterior, motor, horn of the cord, has scarcely been begun at birth ; the fibres grow into the cord during infancy, and are not well developed until the end of the first year.

During the period of growth the branching processes of the cells also develop. They grow longer and more numerous, their interlacings with similar branches and their relation with other nerve cells more complicated and extensive. In is an interesting, and at first sight surprising, fact that in the grey matter of the cerebral cortex of man the nerve cells are farther apart than in, for example, the dog, and in the dog than in the mole. We may conclude that this spacing out is to allow room, as it were, for the development and extension of the branching processes, through which associations are established between different cells in the same part of the brain. The greater the number of such associations the higher the intelligence.

The increase of the brain in weight is very rapid during childhood when new associations are being formed with great frequency, and it continues to increase slowly in bulk until after the twentieth year. The period in which the growth of the brain is most rapid is during the first thirteen or fourteen years of life, and it is to be suspected that new relations between nerve cells are much more readily formed then than at a later age. If faculties and associations are not developed by education during that period, it may never afterwards be possible to call them into existence. During this process of growth and education the simpler associations are first formed, and the more complicated later. For example, an infant first acquires control over the massive movements at the large joints of the limbs, the shoulder and elbow, hip and knee, and there can be no doubt that the same order ought to be followed in the physical exercises, designed to train the muscular system to perform movements promptly, accurately and smartly.

The earliest movements of the limbs made by an infant are bending and stretchings of the shoulder and elbow, the hip and the knee: the first movements of the hand are apparently aimless bendings and stretchings of the fingers. The first concerted purposive movement is an attempt to grasp : the hand is thrust out towards the object, but is often very badly directed, it goes too far,

or not far enough, or to one side or the other; this is due partly to the infant not having learnt to judge distances correctly, and partly to want of education of the nerves and muscles, which have not learnt to obey the will accurately. When the object is touched, the hand does not close upon it with a rapid firm grip, but slowly and uncertainly, one or more of the fingers being bent after the others, and the thumb bent to oppose them only feebly and imperfectly. That the infant quite early forms a clear idea of what it has been trying to do, is shown by the evident pleasure it displays when it has succeeded in grasping the object firmly.

The next advance it makes in its education is to learn to brandish the object, a rattle for instance; the noise pleases it and attracts its attention, so that it repeats the experiment again and again. These movements are made at the shoulder joint and elbow, chiefly up and down movements of flexion or extension. The movements of rotation at the elbow, producing forcible supination and pronation of the hand, are acquired later; as a rule, the position of the hand of a healthy infant is midway between pronation and supination, the thumb and knuckle of the first finger being forward; this is also the position of greatest ease in the child and adult, whether the elbow be bent or the arm be hanging at the side.

When the child goes to school the education of the hand has advanced very much; distances can be judged fairly accurately, it can touch any object with certainty, and the grasp is firm. A great deal, however, still remains to be learnt: how much it is not easy for the adult, who performs the complicated series of movements involved in handwriting almost automatically, to judge. Before the child learns to write, the nervous centres must be educated to co-ordinate the action of many muscles. The shoulder and elbow must be fixed and steadied, and the arm supported so that the wrist is free; next the pen must be held, not roughly and anyhow in the grasp of the palm as the child has taught itself to hold a stick, but in a special way between the first two fingers and the thumb. Then the fine movements, performed chiefly by flexors and extensors of the fingers and thumb, for the formation of the letters must be learnt. In addition to all this the nerve centres for the muscles of the trunk and head must be educated to hold them in their proper postures. In learning to sew, the nervous centres must

be educated to co-ordinate the action of the same groups of muscles, to perform a similar but different set of fine movements: they are rather more complicated because the shoulder and elbow, instead of being fixed as in writing, must move in concert with the fingers and wrist.

The Cerebellum.

The cerebellum (little or hinder brain) lies underneath the back part of the cerebral hemispheres; it has two lobes, right and left, and their substance is arranged in many folds pressed close together like the leaves of a book. The two hemispheres are connected by a broad band of fibres passing across the pons, and large bundles of fibres pass upward to the cerebrum and downward to the bulb. Like the hemispheres, the cerebellum consists of white matter externally, and grey matter at the surface. Very little is known about the functions of the cerebellum; it has something to do with the harmonious working of the muscular system and with the co-ordination of movements, and also with the maintenance of the balance of the body.

The Sympathetic Nervous System.

The sympathetic nervous system, to which reference has already been made in speaking of the circulation and respiration, is in part independent of the cerebro-spinal system. Its relation to the spinal cord is somewhat analogous to that of the cord to the brain, that is to say, it receives nerves from the cord, but also possesses nerve cell centres called ganglia, which can act independently. There are such ganglia for the heart and blood vessels, and for the intestines and other abdominal organs. The nerve fibres which pass between the sympathetic system and the spinal cord are sensory and motor. The sensory carry impressions from the internal organs to the central nervous system; these sensations are chiefly painful, for when the internal organs are healthy we are generally unconscious of their action. The motor fibres carry impulses to the sympathetic ganglia, by which they are distributed to the internal organs.

Fatigue and Rest.

In mapping out the day of children attending elementary schools, the object sought should be to make the wisest disposition

of the hours of work, play and rest, so as not to cram the time-table with subjects so numerous that even the healthiest child must be fatigued, and in time overstrained.

There are two factors in fatigue, the muscular and the nervous. The former has been much more completely studied than the latter, although from the educational point of view, the nervous factor is the more important. Muscular fatigue is produced by toxic bodies, which are the products of muscular activity, and it may be presumed that nervous fatigue is produced in an analogous manner. Just as muscular toxins are eliminated during rest after exercise, in like manner the effete bodies, which come into existence during nervous exertion, are removed when the nervous system rests.

Though it is true that the principal way in which the nervous system obtains rest is by sleep, yet the mere changing of the direction in which the nervous energy flows is in itself a form of repose. Within reasonable limits of exertion, that is to say, short of excessive fatigue or exhaustion, the nervous and muscular activities are, as it were, complementary. By changing from mental to physical work one set of centres is thrown out of action, and another set called into activity, the brain resting some of its parts when physical exercise is taken. Moreover exercise, if taken in the open air or in a well-ventilated room, by quickening respiration and circulation hastens the elimination of the toxic products of activity of the mental centres.

In considering fatigue in relation to the actual time spent at school, account must be taken, not only of the total number of hours of work in a day, but also of the duration of each lesson. The length of time during which the attention can be fixed on a lesson is very short in early childhood and gradually increases :

At 6 years the attention can be fixed for 15 minutes.						
At 7 to 10 years	the attention	can be	fixed	for	20	minutes.
At 10 to 12 „	„	„	„	„	25	„
At 12 to 16 „	„	„	„	„	30	„

Lessons should be short, and followed by periods during which the children take exercise by free play in the school yard or large school hall. This principle is not sufficiently recognised, lessons lasting three-quarters of an hour being usual and intervals too few. Even in classes of small children under five, twenty-five minutes'

recreation only is given during the five and a half hours that the children are in class.

A healthy infant spends a very large part of the twenty-four hours asleep; its longest continuous sleep is for eight or nine hours at night, but it will sleep also for an hour or so several times in the course of the day. Down to the age of four, or even five years, a healthy child if given the chance will sleep for an hour or two in the middle of the day, and for ten or eleven hours at night. As the child grows older the mid-day sleep is given up, but the time spent in bed at night should not at first be curtailed. In fact, a child of eleven or twelve ought to have eleven or at least ten hours in bed, and many children of the poorest classes suffer from insufficient sleep, sitting up perhaps till midnight. As school begins at nine they must be up by eight, and are often awakened by their elders before this.

The following table may serve to give an idea of how a child's day should be spent at various ages:

A Child's Day.

Age under	Sleep.	Dressing, etc.	Meals & Rest.	Free Time.	School.	
					Lessons.	Play.
4 ...	11	1	3	3½	2¾	2¾
5 ...	11	1	3	3½	2¾	2¾
6 ...	11	1	3	3½	3	2½
7 ...	11	1	3	3½	3	2½
8 ...	11	1	3	3½	3½	2
9 ...	11	1	3	3½	3½	2
10 ...	10½	1	3	3½	4	2
11 ...	10½	1	3	3½	4	2
12 ...	10	1	3	3	5	2
13 ...	10	1	3	3	5	2
14 ...	9½	1	3	2	6	2

The Government regulations allow a quarter of an hour's free play each morning in the playground and ten minutes in the afternoon for all children. For the elder ones it would be wiser to give this time in shorter breaks than to give the whole period at once. It should be a time of free play in the large hall in wet weather, and in the school playground in dry. Another alternative is to throw

open the schoolroom windows and allow the scholars to run round the room.

In the infant departments and lower standards, however, this is not sufficient: there should be free movements round the schoolroom, hall or playground, between every two sitting lessons; halls might be more frequently used during the afternoons in infant departments. Organised games and drill lessons should be taken in the playground, and more time given to free arm drawing, which combines eye training and physical exercise, and is valuable, especially in early training.

Drawing as now taught has the following faults:

1. It is merely a copy of the teacher's drawing, and is of uniform character throughout the class.
2. The child having drawn the object set before it sits idle. It should be drawing it over and over again so as to gain facility.
3. The use of chequered paper tends to finicking work.

The children should stand at a blackboard placed at a convenient height round the walls of the schoolroom, the best blackboards are made of canvas, and with head and shoulders thrown back, should draw first with one arm and then the other to attain freedom of movement, doing curves and circles dozens of times. Their sense of imagination should be cultivated by asking them to do spontaneous drawing and memory drawing: a good plan is to tell a story and then ask them to illustrate points which have struck them. Too much stress cannot be laid on wise teaching in this subject, for bad training hinders brain development as well as tending to cramp the body and injure the sight, rendering the children nervous, fatigued and inattentive.

Scholars confined for many hours a day in an elementary school are deprived at once of all the elements necessary to a healthy and normal nervous system: exercise, rest, sleep, fresh air, nourishing food, and this at the great growing period of their life, when all suffer more or less even under the best conditions. We hear every day of children out-growing their strength; by this is meant that the body shoots up so rapidly that there is no time for filling out and fattening, and the child is left thin, and probably mentally as well as physically weakened, at any rate for the time being. This

physical feebleness predisposes to disease: diseases of the joints, tuberculosis, and phthisis; diseases of the nervous, digestive, and circulatory systems; and without a sound body a healthy mind is impossible.

It will be easily seen that excessive expenditure of energy in mental work during this growing period is doubly dangerous. Twenty-five minutes' recreation during five and a half hours' work is insufficient. The best method of getting good work from scholars is to give them short and varied lessons. After twenty minutes or half an hour at one subject the attention wanders, and the child loses interest. German authorities go so far as to recommend that half an hour should be the outside limit for the duration of a lesson, and that after each two lessons of half an hour, a quarter of an hour's play should follow. Time thus apparently wasted is really gained, for if children are forced to concentrate their mental faculties for too long a period at a time they are unable, even after recreation to recover, and the effect shows itself in their work all that day.

The brain cannot get on without sleep, for during sleep only does it rest absolutely. If a human being is deprived of sleep for a long period, his brain becomes diseased. The process of building up the body and the brain from food material is carried on during sleep, and if this is not sufficient, the process will be imperfect and fatigue products will not be cleared away. The earlier people go to bed the more likely they are to sleep well, for they are less likely to be exhausted after the day's work. Exhaustion, *i.e.*, over-fatigue, often keeps off sleep: on this account it is better to go to bed early and get up early, than to go to bed late and get up late.

The brain also requires relaxation after a certain amount of work: a change of ideas. To have a hobby is a real safeguard to those who work their brains much, in order completely to enter into a new world. By this means they are enabled to return to work with renewed energy. Play and recreation relax the brains of school children and ensure better work for the lesson which follows. A mere change of position is restful; standing after sitting quiet, or a lesson done at the blackboard.

The best work of the week is done on Monday and Tuesday after the Sunday holiday; on Tuesday afternoon the work has already begun to deteriorate. A holiday on Wednesday checks mental

exhaustion, and so raises the standard of work for the second half of the week. The first two hours of the day produce the best work; after the midday meal there is a marked falling off, and if a lesson lasts too long the greater part of the class suffers from fatigue. After the holidays the quality and quantity of work are markedly increased. At afternoon school children show a certain amount of exhaustion which lessens their power to work. It would be very wise to give two half-holidays a week, on Wednesday and Saturday, instead of the whole holiday on Saturday. In families where the parents go out to work the children spend Saturday in the street, and where the parents are at home they are forced, probably, to work indoors in unventilated rooms.

Insufficient rest after meals is a common cause of fatigue, and no brain work should be allowed for at least half an hour after eating. A sense of tiredness is also engendered by impure air, and this probably helps to account for the conclusions which experts have come to, that the best work is done during the early part of the day. With the present happy-go-lucky manner of ventilating school rooms, the state of the air in them after a short time is bound to have a depressing and harmful effect.

The effects of eye strain upon the brain should be watched for and prevented. An experienced teacher knows the signs of fatigue, the most common of which are:

The attitude of the hand (as described by Dr. Warner).
The attitude of the head. Lolling attitudes.
Failure of attention. Yawning.
Sleeping in class.

Such signs must be regarded as warnings that there is something wrong in the way the class is being managed. It may be that the room is badly ventilated or insufficiently lighted, that the lessons are too long and the periods of recreation too short, or, in individual cases, that the child comes to school already fatigued from want of sleep, fresh air or food. A good deal of what is set down to over-pressure is really due to neglect of the common rules of hygiene. It is only by maintaining a proper balance between the intellectual and physical faculties that complete and harmonious development can be attained.

All mental action is expressed by movement, and the brain of

a young child is developed by movements. It is of importance to avoid teaching a child under eight such unnecessary and dull things as nouns, verbs, the shape of the earth, and so on. Such methods are not hygienic, for they stunt its intelligence and make it irritable. The secret of successful teaching is to keep the attention fixed, and this is an impossibility in lessons of that kind at such an early age, without resorting to scolding and punishment: by too early aiming at perfection in any subject, the child and the teacher alike are worried unnecessarily.

A great evil of our present system has been, and is, this demand for work of an unsuitable kind at the wrong age. It has been seen over and over again that children of about nine to ten years go back apparently in such subjects as writing, because they began too early. In America, reading, writing and needlework are begun at a much later age than in England and yet the children there have caught up ours by the time they are ten or eleven, and their work is better.

Every child possesses certain faculties which it is necessary to develop: otherwise they die out. Among these may be mentioned the colour sense, the muscular sense, touch, hearing and the faculty of observation, and speech. These are apt to be neglected because the time given to teaching is found all too short for reading, writing and arithmetic. The infant's brain centres, in reality, are not sufficiently developed and connected to control the muscles used in these subjects. Take arithmetic: this should be concrete until the age of seven, when a little written light work might be done. A child may have a talent for drawing, but if that talent is not developed, and if the child is not wisely assisted to cultivate it, the sense of form and colour will gradually diminish. It must not of course be injudiciously forced or taught in the wrong way. This is why in drawing it is so unwise to ask children slavishly to copy the teacher, instead of developing their imagination and originality, often far beyond those of the teacher.

The speech of elementary school children is much neglected, as is evidenced by the manner in which the labouring classes pronounce. Even in their singing lessons they are allowed to drop their "h's" and mangle their English. Teachers should pay attention to this.

VII.—THE SPECIAL SENSES.

SIGHT: The Eye-Balls and Orbit—The Muscles of the Eye—The Coats of the Eye—The Pupil—The Retina—The Optic Nerve—Vision—Accommodation—Myopia—Hypermetropia—Astigmatism—Stereoscopic Vision—The Hygiene of the Eye—School Desks—The Causes of Myopia—Tests of Vision. HEARING: Nature of Sound—The External Ear—The Middle Ear—The Internal Ear—Deafness and its Causes. SMELL AND TASTE: The Olfactory Nerves—Taste. TOUCH AND PAIN: Pain—Touch—Temperature—Pressure—Sense of Position—Muscular Sense.

SIGHT—THE EYE.

The eye lies in the socket or orbit, a funnel-shaped, bony cavity which protects it from injury, while allowing full freedom of movement.

THE ORBIT AND EYE-LIDS.

The eye-balls are further protected by the eye-lids, which are composed externally of skin strengthened at the edge by thin pieces of tough fibrous tissue. Internally they are lined by a thin mucous membrane, conjunctiva, continuous with that which covers the front of the eye itself. The conjunctiva is kept constantly moist by the tears. They are secreted by the lachrymal gland, about the size and shape of an almond, and situated in the upper and outer part of the orbit. The upper lid, larger and more moveable than the lower, covers the whole of the cornea when the eye is closed; it is swept frequently across the eye, distributing the tears and carrying down any dust which may fall on to the conjunctiva. The eye-lids contain a thin eliptical muscle surrounding the opening between them; by its contraction the eye-lids are closed, and by its strong contraction squeezed together. The upper eye-lid is raised by a muscle that arises at the back of the orbit and ends

in a wide, flat tendon attached to the fibrous part of the upper lid. The angles of the eye-lids are called the outer and inner canthus, respectively. On both the upper and lower lid, not far from the inner canthus, may be seen a small aperture, punctum lachrymale. Each leads into a short canal, and these open together into the upper end of the nasal duct. This duct, about half an inch long, passes along a groove in the upper jaw, and opens into the lower part of the nose. If the tears are secreted too rapidly, or if the punctum is obstructed, they overflow and run down the cheek. In addition to the eye-lashes, which help to protect the eyes from dust, the margins of the lids contain the minute orifices of some twenty or thirty sebaceous glands called the meibomian glands. A stye in the eye is due to inflammation of one of the glands.

Chronic inflammation of the margins of the eye-lids and of these glands is not uncommon in children. It often follows measles, but may be caused by dirt and neglect, or irritating or dusty air; errors of refraction predispose to it. The eye-lashes become covered with discharge, the eyes are weak and watery, and the child cannot read or write for long without much discomfort. If neglected, ulceration occurs and the eye-lashes are destroyed. Redness of the eye-lids and soreness and watering of the eyes, even though slight, ought to be medically treated at once.

Trachoma, commonly called blight, is a contagious inflammation of the conjunctiva; it spreads rapidly in schools, especially if the children are underfed or debilitated: it may be acute, but is more commonly chronic. The child complains of a feeling of soreness, stickiness and grittiness in the eyes, and the conjunctiva becomes studded with small granules, whence the name granular ophthalmia, often applied to the disease in this country. If neglected ulceration ensues, the cornea becomes opaque in patches, and the sight may be seriously damaged. It is not easy to cure when once established, and its prevention, by the exclusion of infected children from ordinary school classes, is most urgent.

The hairs of the eye-brows are all directed away from the middle line; they catch perspiration falling from the forehead and conduct it away from the eyes towards the temples: at the inner part of the eye-brows is a small muscle, corrugator supercilii, which knits the brows, drawing them together in frowning.

The Eye-ball and Eye Muscles.

The eye-ball or globe of the eye is nearly a perfect sphere; its diameter from above downwards and from side to side is about an inch, but from back to front rather less than an inch. It has three coats, outer (sclerotic and cornea), middle (choroid) and inner

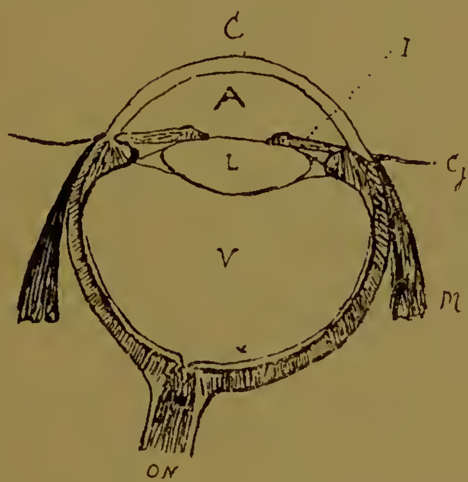


Fig. 15.—Diagram of a Horizontal Section of the Right Eye.

A, anterior chamber; C, cornea; Cj, conjunctiva, where it is reflected from the eyeball; I, iris; L, lens; V, posterior chamber containing the vitreous humour; O.N., optic nerve. The x is placed opposite the yellow spot.

(retina). The outer coat is strong and fibrous and maintains the form of the eye. It consists of two parts:

1. The sclerotic, or white of the eye, covering about five-sixths of the globe; it is opaque and contains blood vessels; the optic nerve enters it at the back, a little (about $\frac{1}{8}$-in.) inside the middle line.
2. The cornea, or clear front of the eye through which light passes. It is made up of many layers of fine transparent fibres and has no blood vessels.

The choroid is a dark brown, rather brittle membrane, lining the sclerotic to which it is loosely attached. It contains many blood vessels and much dark brown, almost black, pigment. In front it is thrown into a number of radiating folds, called ciliary processes, which contain the ciliary muscle, consisting of unstriped fibres;

some are circular, others radiate outwards and backwards to the front of the choroid (Fig. 17).

Attached to the outer surface are the six slender muscles by which the eye-ball is moved. Four of them, one below, one above

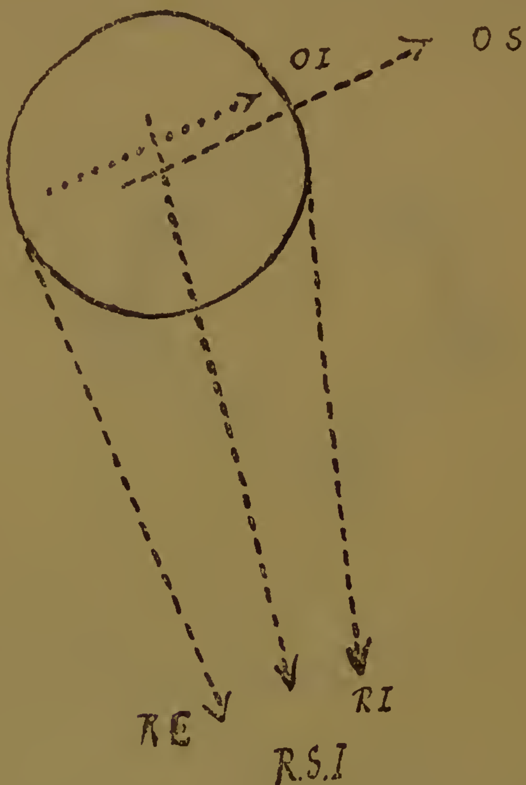


FIG. 16.—TO ILLUSTRATE THE ACTION OF THE OCULAR MUSCLES (LEFT EYE).

Line of action of		R. I.—The internal rectus which turns the eye inwards.			
„	„	R.E.—The external rectus	„	„	outwards.
„	„	R.S.I. { The superior rectus	„	„	{ upwards and a little inwards.
		The inferior rectus	„	„	{ downwards and a little inwards.
„	„	O.S.—The superior oblique	„	„	{ downwards and outwards.
„	„	O. I.—The inferior oblique	„	„	{ upwards and outwards.

and one on either side, are straight, and are, therefore, called the rectus muscles. They run backwards with an inclination inwards, to be inserted into the back of the orbit. They act like reins, pulling

the eye up or down, or to one side or the other. The two other muscles are called the inferior and superior oblique muscles, respectively. The former, attached to the inner side of the orbit in front, passes beneath the eye-ball, to be fixed into its under and back part, it turns the eye upwards and outwards. The latter, attached at the back of the orbit, runs forward to a small fibrous ring, fixed to the bone in front under the eye-brow; its round tendon passes through this ring, and runs backwards, again to be fixed in the upper surface of the eye-ball, just behind the equator. It turns the eye downwards and outwards. The action of the ocular muscles is illustrated in the accompanying diagram, which shows the line of action of each muscle. It must be understood, however, that in any movement of the eye, a single muscle does not act alone. For instance, in turning the eye inwards, the action of the internal rectus, by which this movement is produced, is accompanied by an action of the external rectus, which may be compared to a brake regulating the movement of the eye-ball, so that it is steady and even.

The space between the eye-ball and the bony orbit is filled up by delicate connective tissue, containing a quantity of very soft fat. The eye is kept in place partly by the optic nerve, partly by the orbital fat, and partly by the blood pressure. Consequently, when a person becomes emaciated owing to a wasting illness, and the orbital fat diminishes, the eye becomes sunken. It also sinks during fainting, owing to the failure of the circulation.

The Lens.

The interior of the globe of the eye is divided into two chambers, anterior and posterior, by the lens, which is held in position by a strong, transparent, elastic capsule.

The anterior chamber, which corresponds almost exactly with the cornea, contains a watery fluid called the aqueous humour, in which the iris floats; the posterior chamber, corresponding to the sclerotic, is filled by a gelatinous, transparent substance called the vitreous (glassy) humour or body, enclosed in a fine, transparent, hyaloid membrane. In front the hyaloid membrane joins an important structure called the zonule of Zinn (Fig. 17). This is a fine but strong membrane, which, where it joins the hyaloid membrane, is thrown into a number of closely set radiating folds; into this crimped mem-

brane the corresponding folds of the ciliary processes fit, and the two are united. The zonule of Zinn is thus a flat, circular membrane, like a ring cut out of a sheet of crimped paper, and its inner rim is attached all round to the front part of the capsule of the lens. When the eye is at rest, this membrane is in a state of tension, and by the pressure it exerts, the front of the lens is flattened, that is to say, is made less prominent or convex.

The lens is a circular, transparent body with rounded edges, composed of fine fibres arranged in layers. It is a double convex lens, but is slightly flatter in front than behind, owing partly to the pressure exerted by the zonule.

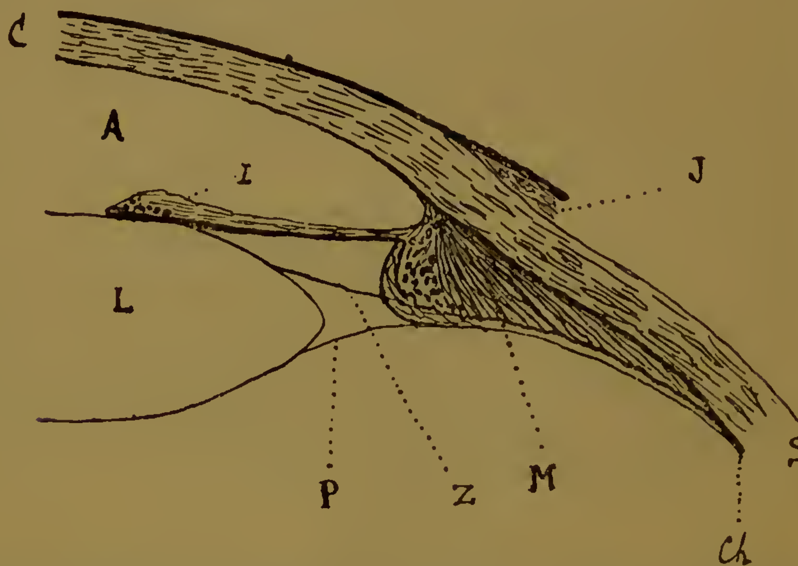


FIG. 17.—DIAGRAM OF HORIZONTAL SECTION OF FRONT OF EYE, SHEWING ONE HALF OF THE CORNEA AND LENS, AND THE CILIARY MUSCLE AND ZONULE OF ZINN ON THAT SIDE.

A, anterior chamber ; C, cornea ; Ch, choroid ; I, iris, with the sphincter fibres cut across ; the dark line on the under surface, represents the layer of pigment which gives colour to the iris ; J, conjunctiva ; L, lens ; M, ciliary muscle ; P, posterior capsule of lens ; S, sclerotic ; Z, zonule of Zinn.

THE IRIS.

The iris, a continuation of the choroid, hangs like a curtain in front of the lens. In its centre is the round aperture of the pupil. The iris contains two sets of muscular fibres, one called

the sphincter, arranged circularly, by which the pupil is made smaller; the other arranged in a radiating manner, by which it is dilated. The iris is very copiously supplied with blood vessels, and on the posterior surface there are several layers of roundish cells, containing black pigment granules. In the blue eye, the colour is due to this dark layer being seen through the unpigmented iris; in the black, brown, or grey eye, there is more or less pigment in the substance of the iris itself; as a water colour may be deepened by another wash of paint.

The pupil contracts in the light and dilates in the dark; it is, therefore, constantly varying in size according to the amount of light which enters the eye. If the reader looks from the printed page to a dark corner of the room the pupils dilate, if he looks at the window or lamp they contract: this is a reflex action, and therefore though rapid, not instantaneous. In going out of a dark room the eye is momentarily dazzled by sunlight, and objects are not clearly seen until the pupil has adapted itself to the brightness; conversely, in going from a brightly-lighted into a dark room nothing can be seen, but gradually, as the pupil dilates, the eye becomes accustomed to the darkness, and many objects previously invisible are perceived. The sharp contraction which takes place on suddenly exposing the eye to light is followed, unless the light is very strong, by a gradual dilatation until the pupil reaches its average diameter, about $\frac{1}{8}$-in. This is due to the power of the retina to adapt itself to a comparatively wide range of illumination. A slow increase in the amount of light entering the eye, causes hardly any contraction of the pupil, whereas a flash of lightning on a dark night produces a strong and prolonged contraction. The iris also acts in accommodation, as will be explained later.

The iris has three uses: (1) it acts like a diaphragm in a camera, cutting off the marginal rays which would cause the image to be indistinct, owing to spherical aberration; (2) it regulates the amount of light entering the eye and so protects the retina; (3) it acts in accommodation.

The Retina.

The retina, or the membrane of the eye by which visual impressions are received, is a very delicate and complex structure. It lies within the choroid, to which it is loosely attached, and is

supported in front by the pressure of the vitreous body. It is thickest towards the back, where almost in the middle, or optic axis of the eye, but a little to its outer side, is the yellow spot or macula lutea, and in its centre a pit called the fovea centralis; it is here that images are most clearly seen. At the point where the optic nerve enters, the sensitive part of the retina is absent, and there is no perception of light; it is therefore called the blind spot.

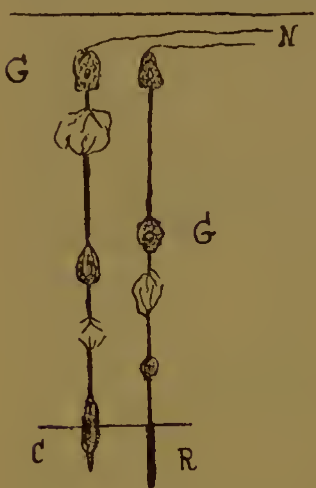


Fig. 18.—Diagrammatic Drawing of a Section of the Retina.

C, a cone; R, a rod; G, ganglion cells in the substance of the retina; N, nerve fibrils going to the optic nerve.

The outer layer of the retina, that on which the image is focussed, is made up of minute cones and rods packed closely together, so that their rounded ends form a mosaic surface. The cones are minute, flask-shaped bodies. The rods in their outer part contain a red pigment called "visual purple," which is bleached by daylight and is continually being reproduced. At the yellow spot, where vision is most acute, there are cones only; near it each cone is surrounded by a ring of rods; the further from the yellow spot the fewer the cones, and as vision is less sharp in the outer parts of the retina, it is concluded that the cones are more important for vision than the rods. The retina of the lizard contains cones only, and in the eye of all birds except the owl there are many cones. As the acuteness of vision of lizards and of most birds is proverbial, this confirms the opinion that the cones are the important elements in clear vision.

The remainder of the thickness of the retina has been divided into many layers by anatomists, but it is made up of tissues having

the same chemical composition as the grey matter of the brain, and may therefore be called the nervous layer. In fact, it may almost be regarded as an expansion of the brain. The innermost part of the retina, which is bounded by a thin limiting membrane, consists of an immense number of minute nerve fibrils, naked axis-cylinders, variously estimated at from half to three-quarters of a million in each eye. The cones and rods give off fine fibres, indirectly connected by ganglion cells, in the nervous layer with the nerve fibrils. There are about seven cones, and one hundred rods to each nerve fibril.

The optic nerves after leaving the eye, incline backwards and inwards, and enter the cranium by the foramen magnum at the back of the orbit. At the base of the brain they appear to cross each other, but in fact this crossing or decussation is incomplete, only half the fibres going over to the other side. The left half of the retina in both eyes belongs to the left optic nerve, and the right half in both eyes to the right nerve. The optic nerves contain two sets of fibres, the visual, or sight fibres, and the pupillary. Beyond the decussation, the fibres of the optic nerves, now called the optic tracts, enter the brain and can be traced on each side to the psycho-visual centre and the pupillary centre respectively.

Vision.

The eye may be compared to a photographic camera. The essential parts of a camera are the lens to focus the picture, and the sensitive plate to receive it. The lens of the camera represents the crystalline lens of the eye, and the sensitive plate the retina, the resemblance being all the greater in the latter case, because light temporarily discharges the colour from the retina, visual purple. To this is due the fact that the impression of a bright image persists for some little time after the eyes are closed. The comparison may be carried further: the photographer must have a means of altering the focus, so as to obtain a clear image of either a distant or a near object; he must have a series of diaphragms, so as to admit more or less light into his camera, the interior of which must be blackened to prevent reflexions within, and he must have some way of directing the instrument upwards or downwards, to the right or to the left, towards the object to be photographed. The focussing apparatus of

the camera is represented by the system of accommodation of the eye, the diaphragms by the iris which regulates the amount of light entering the eye, and the blackened interior of the camera by the choroid. The photographer's power of directing his camera in any direction is conferred on the eyes by the ocular muscles, and by the movements of the head as a whole.

Vision is most acute, as has been said, at the fovea centralis. It grows gradually less acute, until, near the ciliary body it is very faint. Consequently, when we want to see an object distinctly, we turn the eyes automatically so as to bring the image exactly on to the fovea; this is termed direct vision; the movement of the adjustment is called fixation. Images which fall upon other parts of the retina are less sharply defined, and this is indirect vision. The whole that can be seen by both direct and indirect vision is the field of vision; in the case of either eye separately it is larger on the outer side, because the nose limits it on the inner.

Accommodation.

Accommodation is the term applied to the power of the eye to form on the retina clear images of both near and distant objects. It is a somewhat complicated action, but is due mainly to a mechanism by which the lens is rendered thicker or thinner, more or less convex.

When the eye is at rest it is accommodated for distant objects, and for practical purposes, all objects more than twenty feet away may be considered distant. If, with a normal eye the eye-lids are closed and on opening them distant objects are seen clearly at once, there is no need for accommodation; a near object, however, is not seen distinctly for it is not in focus. It is focussed by an alteration in the shape of the lens which becomes more convex. As has been said, the front of the lens is slightly flattened by the pull of the zonule of Zinn (Fig. 17, z); this membrane is connected behind with the ciliary body. When the eye is to accommodate, the ciliary muscle (M) contracts, and by pulling forward the choroid (Ch.) relaxes the tension of the zonule of Zinn, and the lens by virtue of its elasticity becomes more convex, that is to say, thicker. As the back of the lens is supported by the firm, gelatinous, vitreous body, its front surface as it becomes more convex, protrudes further for-

ward. In accommodation for near objects the pupil contracts, and this movement contributes to the relaxation of the zonule of Zinn, as it pulls the ciliary body slightly forward. When the object looked at is quite close to the eye a further movement occurs. If a person reads with the book very close to the eye, or if he be asked to look at his nose, it will be seen that he is squinting; both eyes have turned inwards; this is called convergence. This occurs also when fine work of any kind is done; a large percentage of the children in infants' classes doing needle and other work may be seen squinting. This is inevitable, for owing to the formation of the undeveloped eye, the work cannot be focussed at the proper distance of twelve inches. It is obvious that fine work is unsuitable in the lowest standards and leads to many evils later on.

Writing in lines is begun far too early, at three years. It should be taught in the form of drawing first, and children should be able to draw freely all letters, figures, and little words in large size before they use lines. At six years of age, one line only should be given at first as a guide, later on two lines to secure uniformity of size, but no time should be wasted in getting uniform class results from which all books, etc., seem to have been through the hands of one child. This aim at uniformity in written exercises and in working out arithmetic papers, is killing the good work in hundreds of schools, infants', boys', and girls' departments. Inspectors unfortunately too often look for it. Each child's book should show progress, and that should be the teacher's aim.

Refraction.

A bi-convex lens, such as an ordinary pocket magnifying glass, has two convex surfaces. The centre of each of these surfaces is called the centre of curvature, the imaginary line joining the two centres of curvature is called the principal axis of the lens, and the middle of this line the optical centre of the lens. Rays of light which pass through the optical centre are not bent; rays which pass through any other part are.

Parallel rays, parallel that is to the principal axis, are so refracted that they meet at a point on the opposite side of the lens which is the focus of the lens, and at this point a clear image is produced. The image is inverted, that is to say, upside down (Fig. 21). There is

of course, a focus on each side of the lens. Rays which come from an object nearer the lens than its focus, are divergent when they strike the lens; they are bent, or refracted, in the lens but do not come to a focus, so that a clear image is not produced The greater the curvature of the lens the more the rays are bent, and the shorter focus; the nearer therefore to the lens is the point at which the image is produced. A bi-concave lens produces the

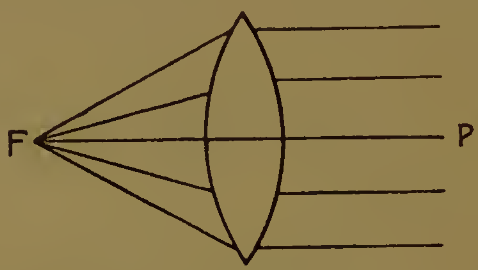


FIG. 19.—REFRACTION OF PARALLEL RAYS IN A CONVEX LENS.

F, focus where the image is formed; PF, ray passing through optical centre of lens and not refracted.

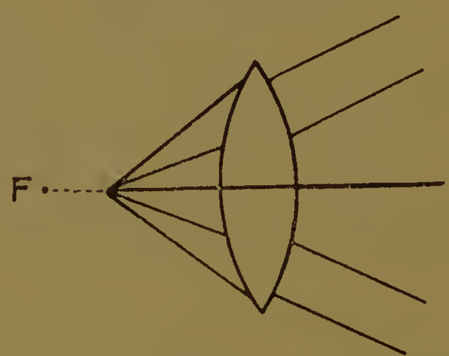


FIG. 20.—REFRACTION OF RAYS FROM A SOURCE WITHIN THE FOCAL DISTANCE.

opposite effect, that is to say, parallel rays passing through it are made to diverge, and divergent rays to diverge less, or to become parallel.

The eye, as has been shown, consists of several refracting media, cornea, lens, vitreous, etc., but for practical purposes its total refraction can be calculated. The total refraction of any eye can be altered by variations in the curvature of the lens in accommodation, and in this way only.

The normal eye is so made that when at rest parallel rays, that is to say rays from any distant object, come to a focus on the retina, and form there an image of the object (Fig. 21). By the increase in the convexity, or thickness, of the lens produced during accommodation, the amount of refraction is increased, and thus rays from near objects are likewise brought to a focus on the retina. A normal eye by the strongest effort of accommodation, can obtain a clear image of an object no more than five inches from the eye. To get a clear image of an object nearer than that, a convex glass must be used to reinforce the refractive power of the lens of the eye. By thus bringing the eye nearer to the object the image on the retina is made larger, and the object is therefore said to be magnified.

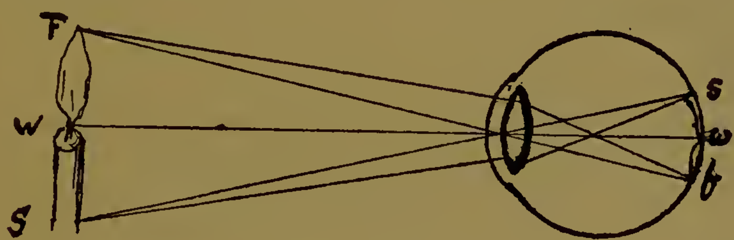


FIG. 21.—SHEWING INVERSION OF IMAGE ON RETINA, f, w, s, CORRESPONDING TO F, W, S.

Myopia.—The short-sighted or myopic eye is longer than normal. The refractive power being the same, it will be obvious that in such an eye parallel rays will be brought to a focus, not on the retina but more or less in front of it. On the other hand, certain divergent rays, those from a near object at a certain distance, are brought to a focus on the retina. Hence, such an eye is said to be near-sighted or short-sighted. The distance at which an object must be in order that its image shall be in focus on the retina, varies of course with the degree of deformity of the eye. This defect of the myopic eye may be corrected by the use of a bi-concave glass of the proper curvature, to focus parallel rays on the retina. The degree of myopia is measured by the strength of the glass needed to correct it.

Hypermetropia.—The hypermetropic, so-called far-sighted eye, and the presbyopic eye, or eye of old age, is the opposite of the myopic eye; it is too short. Consequently parallel rays entering it

would come to a focus, not on the retina but somewhere behind it. Convergent rays on the other hand can be brought to a focus on the retina. As all rays are either parallel, from distant objects, or divergent, from near objects, a clear image can never be focussed on the retina of a hypermetropic eye at rest. By an effort of accommodation parallel rays may be focussed on the retina. So also may rays which are slightly divergent. As will be understood from what has been said, the ciliary muscle is almost constantly in action to produce accommodation while a hypermetropic eye is in use. This over-use causes a feeling of strain in the eye, and often leads to head-

V

H

Fig. 22.—Diagram to Illustrate Distortion of Image in Astigmatism.

V, when the irregularity is in the vertical; H, when it is in the horizontal diameter.

aches. Hypermetropia can be corrected by using a convex lens of proper curvature, and in this way the constant strain on the ciliary muscle is relieved.

Astigmatism is another kind of defect in the refraction of the eye. In it the curve of the cornea may be regular in one part but irregular or uneven in another, like a pane of badly blown glass. The image of an object seen through the irregular part of the curve is blurred; if, for instance, a cross be looked at, the arms running one way will be seen distinctly, those running the other will be foggy or irregular (Fig. 22). The defect, which is congenital, and often associated with hypermetropia, may be the real cause of inability to fix the attention on fine work. It may also produce headache if the eyes

are much used for such work. It can be corrected by special glasses calculated to neutralise the unevenness of the cornea.

Stereoscopic Vision.

The two eyes always move in association, that is to say, both eyes move together upwards or downwards, to the right or left, and to the same extent, except in convergence for near objects, when both globes move inward. The movements are regulated by the visual centre in the brain and are voluntary, but the consentaneous movement of the two eyes is beyond the control of the will. We cannot look to the right with one eye and to the left with the other. The image of an object, therefore, always falls upon the retina of both eyes at the same time. The image falls upon corresponding points in each retina; the yellow spot in the one eye corresponds to the yellow spot in the other, and so with every other point in the retina, each has a corresponding point in the other eye. The images formed at the corresponding points are combined by a psychical act at the same point in the field of vision, so that only one image is produced in the mind. Yet the images of a solid body produced in the two eyes are not exactly alike. The right eye sees more of the left side of an object, and the left more of the right side. The combination of the two images gives the impression of solidity; that is to say, stereoscopic vision. How this sense of solidity is obtained is not quite clear; it is perhaps partly due to our consciousness of slight variations in the degree of convergence, due to slight differences in the distance of the parts of an object; but probably in the main to experience. The child apparently learns that an orange, for instance, is globular by feeling it; it then learns to associate the form and shading with a globular object.

Hygiene of the Eye.

As teachers are in a large measure responsible for the care of the eyesight of children in their classes, and as they have to test their eyes to discover defects, it is necessary that they should be able to put into practice the theory which they have learnt.

The conditions of the school-room must be taken into consideration as regards:

1. The amount and proper distribution of daylight and artificial light.

2. The shape of the desks.

3. The description and amount of work done, according to age.

(*a*) The daylight should fall upon the desks from the left hand side. In no case must the windows face the children, and if windows are placed behind, the body and head throw a shadow on the book. A teacher is powerless to remedy faulty lighting due to defects in the construction of a room, but he may be able to place the desks more favourably, and to represent to the inspectors the danger of the unfavourable conditions mentioned; he can also insist that the windows shall be cleaned oftener than once at the commencement of the term.

With regard to artificial lighting, the lights must be placed over, and never in front of, the children's eyes; as light varies in brightness inversely as the square of the distance from the source in order that the whole class may see the lights should be distributed, rather than in one large central cluster. Clear globes give most light, and reflectors may be used to throw the light downwards, the shades to be green outside if possible, so as to act as a protection to the teacher who is obliged to face the glare. He should have a separate, green-shaded lamp on his own table.

If the head teacher is consulted about the colour of the walls, he should suggest the soft water green so much used in schools abroad, as being restful to the eyes.

(*b*) In the matter of desks, as children sit at them for long hours they should be selected with great care. Dual desks are bad, tending to cramped, unnatural positions. Continuous desks with single, pedestal chairs, known as the Sheffield system, are recommended, one of their advantages being that the children can easily get out of their chairs and stand beside them, for reading or other suitable lessons. The back requires support, and in order to supply this, the edge of the desk should project slightly beyond the edge of the seat, so that the child can sit straight up. A gentle slope, say from fifteen to twenty degrees, is necessary, and it should be possible to raise it, so that the book when resting upon it is at an angle of about forty-five degrees, or not less than twelve inches from the eyes. For the youngest children flat tables or desks are most suitable. At present,

in teaching freehand drawing, the children are seated at their desks, at the extreme outer edge of which small drawing boards are fixed into a groove, quite upright without the smallest slant. The term freehand indicates freedom of movement, yet here from the cramped sitting posture and the upright board, the back and the eye are strained, and the arm, wrist and hand rendered unsteady. No architect, artist or engineer draws on a board placed vertically on an easel; the board slopes to assist the eye and hand. In all schoolrooms there should be gently sloping canvas blackboards round the sides of the walls, placed so as to suit the average height of the children.

The healthy eye in infancy is short and flat, but the lens is rounder and more elastic than in later years, so that accommodation is easier. During childhood the eye gradually grows longer, but it is not until about the age of eleven that it attains the normal length in proportion to its other dimensions.

In hypermetropia complete development is arrested, and the eyes being short from back to front, practically remain in the infantile state. If the hypermetropia is severe enough to prevent useful vision, a condition often accompanied by squint one eye only being used, or if the strain on accommodation produces congestion of the eye or headache, the use of glasses will probably be necessary.

In myopia the posterior parts of the sclerotic and choroidal coats are thinned, proving that the elongation of the axis is due to a stretching of the coats of the eye. Most authorities agree that the disease is not congenital, and that it must therefore be produced by some mechanical cause. This is the compression of the eye-ball by the ocular muscles, during the excessive convergence necessary for the close distance at which myopes work: the compression causes distension of the eye backwards and the tendency is increased by congestion.

The causes of myopia may be classed as predisposing and determining:

1. *Predisposing.*—The most important are hereditary predisposition and mal-nutrition, whether from disease or want of food.

2. *Determining.*—Any causes producing congestion of the eye, whether excessive convergence or accommodation for close work;

the leaning and bending forward of the head, due to badly constructed school desks; working in a bad light; the strain on the optic nerve and the increased action of the oblique muscles, combining to increase the diameter of the eye. Heredity does not concern the teacher, but cases of mal-nutrition should be pointed out to the medical officer for investigation. It is significant that children are never born myopic: the disease generally begins to becomes troublesome at the age of eight or nine, but causes which produce it must have been at work before this. The proportion of children suffering from it steadily increases from the younger to the older in schools. Investigations made recently in some of the London schools showed that at six years 81 per cent. had normal vision, and only 3·5 per cent. serious defects; but at every quarter of a year of age afterwards there was an increase in the defects, until, at eight years, only 77 per cent. had normal vision, while 8 per cent. had serious defects; this proportion increased, until at 11 years it was 11 per cent. This means that in London alone at least 25,000 children are being seriously handicapped in all their pursuits. Myopia accounts for a large part of the bad sight placed under the heading of "serious defects." Even where after that age it is not severe at the time, it must be regarded as a serious condition, inasmuch as it is probable, not only that the error of refraction itself will increase, but that it will tend to disease of the retina, which diminishes the acuteness of vision and may eventually lead to blindness. What makes this infinitely more serious is that, in addition to the harm done to these children's sight by school work not adapted to the visual capacity of the young, there is the strain thrown on the developing nervous system. This chiefly applies to the infant classes. How much a child in the infant class has to learn in relation to the senses must always be remembered. Its higher centres have to become co-ordinated; it has to understand how to combine impressions received from the organs of vision, hearing and tactile sensation, so as to obtain a complete mental conception of an object: for example, it has to learn to associate the form of a letter with its sound. If we add to these natural difficulties artificial obstacles, the strain on the nervous system must be increased until it produces distinctly injurious effects, not only upon the eye but also upon the development of the intellect. It is

difficult enough to rivet a child's attention: if then the object the child is expected to see and understand is too small or insufficiently lighted, its attention wanders. Now the cultivation of the faculty of attention is one of the most important parts of the teaching in an infant school. Again, with regard to the rule that the object must be so placed as to be within 12 inches from the eyes in order to obviate stooping, its observance is equally important for the spine and bones generally. A faulty attitude is the commonest cause of lateral curvature and narrow chest (Plate XVI.).

Bad habits formed in the infant department become fixed if passed over: infant's eyes must not be overworked or strained; a sufficient working distance must be maintained betweeen the eyes and the work; the child's mental powers must not be developed at the expense of its physical. Many experts distinctly lay down that the time given to reading, writing and sewing under the age of seven is so much time wasted; it should be devoted to the formation of character, brain training and development of the senses. It is during this time that the coarse movements of the limbs should be acquired by such subjects as freehand drawing, in order that the child may gain motor control. Later on it will be time enough for mechanical things, such as sewing, which requires steadiness of hand and precision of eye.

Tests of Vision.

It is the teacher's duty to test the eyes of the children in the class; for the purpose of testing, a series of graduated letters on a card is used. The cards generally used are Snellen's Test Types, which are fixed on a board. The top letter should be read at sixty metres, it is marked in small outlined letters, D=60; the second row, 36 metres; third, 24; fourth, 18; fifth, 12; sixth, 9; and seventh, 6. The child who is going to be tested stands twenty feet, six metres, in front of the card, which should be hung in a good light. He ought to be able to read all the letters correctly with either eye, such a result being recorded as $V=\frac{6}{6}$. The numerator expresses the distance in metres at which the child stands, and the denominator the distance at which the smaller letter distinguished ought to be read. If with the right eye the child has only read the first three lines, it will be recorded

R.V. $= \frac{6}{24}$, any fraction less than unity denoting defective visual acuity.

The testing of the eye should be done with care and patience, and teachers should, in the first instance, not take upon themselves more than calling the attention of the Medical Officer to cases requiring special examination. But once spectacles or remedies are prescribed it is clearly the teacher's duty to see that the treatment is carried out. If parents do not act upon the advice they receive, teachers should write again and again to them until the instructions are carried out. At present there are complaints that the spectacles are often forgotten at home and often broken there. Inasmuch as in most cases the glasses are for use at school, they should be kept by the school teacher. The name of each child could be printed on the case or pasted inside the flap.

THE EAR AND HEARING.

The organ of hearing comprises the ear, the auditory nerve and certain centres in the brain.

Sound is produced by longitudinal waves of certain lengths produced in elastic bodies. The velocity of sound transmission in air, is about 375 yards a second; in water it is about four times as rapid, and in solid sonorous bodies, from seven to eighteen times as rapid as in air. Sound is weakened when it passes from one medium to another. Sound waves are reflected when they strike a solid surface, the angle of reflection being equal to the angle of incidence.

The Ear.

The ear consists of three parts, the external ear, the middle ear, and the internal ear. The two latter are contained within the dense structure of the petrous part of the temporal bone.

The External Ear.

The external ear is composed of the auricle, or flap of the ear, and the external auditory canal. The flap of the ear is formed of cartilage possessing the well-known characteristic shape, covered by skin. The deep central cavity of the flap is called the concha (shell). At the bottom of the concha is the opening of the external auditory canal, which runs inwards. The outer part of the wall of

the canal is formed of cartilage, the inner of bone, and it is lined by skin. In the skin just within the opening are a number of large ceruminous glands which secrete wax (*cera*, wax). The canal is closed by the drum of the ear or tympanum, a thin semi-transparent, but tough sheet of membrane, nearly circular.

The Middle Ear.

The middle ear, or tympanic cavity, is contained within the temporal bone. Its outer wall is formed by the tympanic membrane. It communicates (1) with certain cavities in the mastoid part of the temporal bone, called the mastoid cells; and (2) with the pharynx by the eustachian tube, about one and half inches long, lined with ciliated mucous membrane; the tympanic cavity and the mastoid cells are also lined with mucous membrane. There is thus a direct communication between the throat and the middle ear; inflammation starting in the throat may extend along the eustachian tube into the tympanic cavity, and thence to the mastoid cells. This happens not infrequently in measles and scarlet fever. The inflammation in the middle ear may be sufficiently intense to cause perforation of the drum, and the matter, or pus, then escapes by the external auditory canal. The inflammation causes intense pain, which is at once relieved when the drum bursts, allowing the pus to escape. The side of the tympanic cavity opposite to the drum is formed of bone, in which are two small openings closed by delicate membranes; the one opening is rounded, and is called the fenestra rotunda, the other is oval, and is called the fenestra ovalis. Passing across the cavity of the tympanum is a chain of small bones, the ossicles of the ear. One called the malleus, from its likeness to a hammer, is attached by its handle to the drum; the third, called the stapes, because it is exactly like a stirrup, is attached by its plate to the membrane closing the fenestra ovalis; the second, which lies between the other two and articulates with both, is called the incus, from a fancied resemblance to an anvil. Waves of sound falling on the drum, are transmitted by this chain of bones to the fenestra ovalis, and so to both parts of the internal ear. They are also doubtless transmitted through the air in the tympanic cavity to the fenestra rotunda, and thence to one part, the cochlea, of the internal ear. Attached to the ossicles are two small muscles, the tensor

tympani, which is inserted into the neck of the malleus, and the stapedius, inserted into the upper part of the stirrup (stapes). By the action of these muscles, the tension of the drum and the pressure on the fluid in the internal ear are regulated.

The Internal Ear.

The internal ear, called also the labyrinth from the complexity of the winding canals of which it is made up, is contained within the petrous part of the temporal bone. The bony canals are lined by highly specialised mucous membrane, and the whole is filled with fluid in which the terminations of the auditory nerve float.

The auditory nerve has two functions, it is not only the nerve of hearing, but also that nerve by which the equilibrium of the head and body generally is maintained. Correspondingly, the internal ear consists of two distinct but communicating parts, the one the cochlea, concerned with hearing, the other the semicircular canals, concerned with equilibrium. In the horse and sheep there are two separate nerves going to these two parts of the internal ear. In man they are united into one nerve, but the two sets of fibres can be distinguished, the one set, fine, going to the cochlea, the true nerve of hearing; the other, coarser, going to the semicircular canals. The fine fibres are connected with the pyscho-auditory centre in the cortex of the temporal lobe of the brain, the others with the cerebellum, which is concerned with the sense of position and with the maintenance of the equilibrium of the body.

Fig. 23.

Cochlea (C) and semicircular canals (S).

The cochlea is a coiled canal which makes two and a half spiral turns upon itself (Fig. 23, c). The canal, which is filled with a clear fluid called endolymph, is divided into two by a septum, which extends horizontally for the whole length of the spiral. A small part of the uppermost of the two canals thus formed, is separated

from the rest, and in this small partition, the cochlear canal (Fig. 24, c), are spread out along the whole length of the spiral, the terminations of the auditory nerve forming what is called, after its discoverer, the organ of Corti.

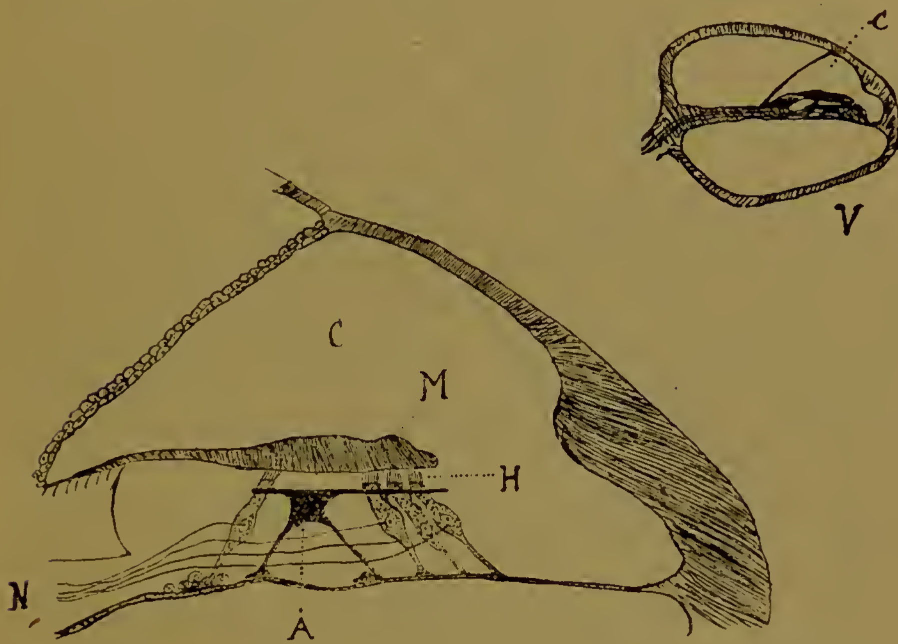


Fig. 24.—Diagram of the Cochlear Canal containing the Organ of Corti (endings of Auditory Nerve).

A, arches of Corti; C, cochlear canal; H, auditory nerve cells with terminal hairs; M, soft membrane of Corti; N, fibrils of auditory nerve going to the auditory nerve cells; V, diagram on a smaller scale of a cross section of the cochlea to show the position of the organ of Corti (C).

This consists of two parts: a supporting structure called the arches of Corti (Fig. 24, A), arranged like the two posts and cross-beam of a Chinese doorway, and the nerve cells called hair cells, because their free ends have many stiff hair-like fibres (H) projecting from them. These cells, which are the actual end organs of the auditory nerve, number some seventeen or twenty thousand in the ear of man. Lying over the hair cells is a soft membrane, (M) called the membrane of Corti; it is believed to act as a damping apparatus.

Disease of the cochlea produces first disturbances of hearing, noises in the ear, etc., with diminution of acuteness of hearing, and finally complete and incurable deafness.

Sound waves, as has been said, are, under ordinary circumstances, conducted to the auditory nerve through the air, by way of the external auditory canal, drum and tympanic cavity; they may also be conducted through the bones of the head. If the handle of a vibrating tuning fork is held between the teeth, its note is loudly heard; if, however, when it has died away the fork be brought quickly close to the ear, it will be heard again, showing that the auditory nerves are more easily excited by sound waves which reach them in the ordinary way. The sound of a tuning fork in contact with the skull or with the teeth, is heard better if the ears are stopped. If, in a person who is partly deaf or hard of hearing, a tuning fork in contact with the skull is well heard, it is a proof that the disease is not in the internal or nervous part of the ear, but in the middle or external ear.

The semicircular canals are three horse-shoe shaped tubes, opening into a common cavity called the vestibule, on the opposite side of which is the fenestra ovalis, filled by the stapes. One of the canals is horizontal; the two others curve upwards, but one is in a plane from front to back, the other from side to side (transverse); in this way there is one tube in each of the three dimensions of space. Each tube is dilated at one end, the enlargement being called the ampulla; the branches of the auditory nerve end in the ampulla in hair cells, like those in the cochlea.

Disease of the semicircular canals causes giddiness, often accompanied by noises in the ear, vomiting and staggering gait (Ménière's disease).

Our estimate of the direction from which a sound comes is formed, partly owing to the impression being louder on that side this is assisted by turning the head a little to one side and the other; and partly by the aid of the semicircular canals, a sound coming from one side striking the canals on that side more forcibly than on the other.

Deafness.

A large percentage of the children attending elementary schools suffer from deafness in a greater or lesser degree. The most

common cause of deafness in childhood is disease of the middle ear, and the most common disease of the middle ear is inflammation, extending from the throat. The inflammation of the throat, which occurs with scarlet fever, measles or diphtheria, may extend along the eustachian tube to the middle ear; the obstruction produced by adenoid vegetations may have the same result. Inflammation of the middle ear causes severe ear-ache, and if neglected perforation of the drum of the ear, with eventually destruction of the ossicles. The inflammation may extend to the mastoid cells (p. 18) and may lead to abscess of the brain.

Adenoid vegetations are groups of tumours in the naso-pharynx; they interfere most seriously with the nasal functions, and may lead to inflammation of the middle ear. In severe cases the adenoid tumours hang down like a curtain behind the posterior nares into the naso-pharynx, and block the opening completely. As a result of this partial or entire blocking, breathing takes place through the mouth: hence the name of mouth-breathers.

Adenoids are common among all children under the age of fourteen; it is very important that they should be treated medically as early as possible, for two reasons, (1) because the operation in the early stages is comparatively simple; (2) because adenoids, if not treated, lead to most serious complications. Among these are deafness; a predisposition to consumption, owing to the serious chest deformities produced by the strong action of the diaphragm in the effort to fill the chest; the work of the heart and circulation is carried on at a disadvantage; a characteristic appearance of dulness and stupidity caused by the open mouth, which, in old-standing cases, is never lost, and seriously handicaps those seeking for employment; the laterally compressed nose; the veiled look about the eyes; the absence of resonance in the voice, leading to the faulty enunciation of the letters *m* and *n;* the impossibility of fixing the attention on a particular subject, and premature brain fatigue, due to the inability of the intracranial lymphatics to remove waste products.

The teacher ignorant of these facts, may regard a child suffering from all or some of these symptoms as "backward"; its dull appearance, indistinct speech and inattention are attributed to moral rather than to physical defects, and the matter becomes

very serious when children, who free from adenoids would be intelligent and capable of profiting by their education, are punished and disliked by teachers to whom they are a constant source of worry and discouragement. For their own sakes, then, as well as for the children's, all teachers should look out for suspicious cases of sore throat, ear-ache and adenoids, and at once report them to the Medical Officer.

SMELL AND TASTE.

The senses of smell and taste are very closely associated. The taste of any substance depends very largely on its aroma, so that if the nostrils are filled with water or blocked up, very little power of discriminating by taste is left.

Smell.

The general structure of the nose has been described in the section on respiration (p. 50).

The nerves of smell, the olfactory nerves, though generally so-called, are really lobes of the brain. They rest on the cribriform plate of the ethmoid bone, behind the bridge of the nose and immediately above the nasal cavities, into which they send down eight or ten filaments. The minute branches of these filaments spread out in the mucous membrane of the upper part of the nose, and end in the olfactory cells, specialised epithelial cells, with a spindle-shaped body and a long rod reaching to the surface; from its free end project six or eight fine olfactory hairs. It is believed that odours, which are volatile substances, produce the sensation of smell by coming in contact with these hairs.

The sense of smell is a kind of sentinel warning us against bad air and bad food, and to some extent guiding in the selection of good food. The sense is abolished, or very much diminished, by inflammation of the mucous membrane, as in a cold in the head; it is very imperfect in children who, owing to adenoid vegetations, breathe through the mouth instead of through the nose.

Taste.

The sense of taste resides chiefly in the back of the mouth, that is to say, at the back of the tongue where, as has been said in the

description of that organ (p. 70), the taste buds are most numerous, and in the soft palate; but it exists also at the tip and sides of the tongue.

There are four different kinds of taste: sweet, bitter, sour and salt; but in all cases, in order that a substance may be tasted, it must be dissolved in water or in the fluids of the mouth. The more concentrated the solution, the stronger the sensation it produces.

The chief nerve of taste is the glosso-pharyngeal, which supplies the back part of the tongue. Its finest branches surround the taste bulbs with delicate fibrils.

Taste assists in the choice of wholesome food; but its importance in this respect is greater in many of the lower animals than in man, who relies more upon his intelligence in making the selection.

TOUCH AND PAIN.

The fibres of the sensory nerves are of two kinds, those that convey sensations of pain, and those that receive and transmit sensations of touch (tactile impressions).

Pain.

The nerve fibres conveying painful impressions, are distributed not only to the skin, but also to all the internal organs and tissues, including bones, tendons, and ligaments; the tactile sense is limited to the skin, mouth, throat and orifices of the body, and is wanting in most internal organs. Any kind of irritation of the sensory nerves, if strong enough, causes pain, and the sensitiveness of different nerves in this respect varies: pain is felt more acutely in the face and abdominal organs than elsewhere. Speaking generally, the larger the number of nerve fibres involved, and the longer the irritation continues, the more intense the pain. Inflammation of a part heightens sensations of pain in it. If a healthy ligament, for instance, be cut little or no pain is felt, but if inflamed, the lightest touch causes acute suffering. The sense of pain is, as a rule, much less definitely localised, and requires a much stronger stimulus to excite it than the sense of touch. Slight irritation of the pain fibres produces sensations of tickling or itching.

Touch.

The sense of touch is complex, being made up of sensations of (1) pressure, (2) temperature, and (3) relations in space. There are special nerve fibres for the sensations of pressure, of heat, and of cold. Each fibre ends in a distinct area of skin, so that the sensitive surface is formed of series of small areas or points, some receiving and conveying sensations of pressure, and others those of temperature.

Temperature.—There are separate temperature points for heat and cold; the latter are the more numerous, and, speaking generally, the sensitiveness of the skin is greater to cold than to heat. Very slight differences in temperature can be recognised by the finger tips, but, as a rule, a temperature seems to be higher if applied to a large than to a small surface.

Pressure.—Sensations of pressure are received at points distinct from the temperature points. The number of pressure points in different parts varies; they are very much more numerous on the pulp of the fingers, for example, than on the back. The acuteness of the pressure sense is measured by studying the sensations produced by weights. The sense is most delicate on the forehead, temple, back of hand, and forearm, where very light pressure can be perceived: the perception of slight differences between two weights, however, is keenest in the finger tips.

Sense of Position.—The brain can localise the position from which it receives a tactile impression, but the precision with which this can be done varies, being very great in the tip of the tongue and the pulp of the fingers. The sensitiveness in this respect is tested by pressing the points of a compass on the skin, and noting the distance between them when they cease to be perceived as two. In the adult the two points if pressed on the back, produce the impression of one when they are as much as 67 millimetres apart; at the tip of the finger they are perceived as two when a little more than two millimetres apart; and at the tip of the tongue when a little more than one millimetre apart. A child's perceptions in this respect are more acute than an adult's.

Muscular sense.—The muscles are supplied with sensory nerves, which convey to the brain a knowledge whether the muscle is in

activity, and the degree of action. The weight of an object is estimated by the brain, from a knowledge of the degree of muscular contraction required to overcome the resistance of gravity, assisted by the information given by the pressure sense on the skin: the former is more delicate than the latter. The upper limb can recognise a weight of 1 gramme, and an addition of 1 gramme to an original weight of 15 grammes, of 2 grammes to an original weight of 50, and of 3 to an original weight of 100. The power of discrimination can be improved by practice, and is often possessed to an unusual degree by blind persons. It has been pointed out above, that a knowledge of the position of the body, and of the direction of movements is derived from the semicircular canals; but these indications are supplemented by those supplied by the muscular sense and the pressure sense.

VIII.—THE MUSCULAR SYSTEM.

Involuntary Muscle—Voluntary Muscle—Its Structure—Chemical Composition—Contractility—Mode of Contraction—Anatomy of the Muscles—Action of the Joints—Development of the Muscular System—Nutritive, Corrective, and Control Exercises—Educational Effect—The Syllabus of Physical Exercises—Standing—The Position of Attention—Standing at Ease—Head Exercises—Trunk Exercises—Shoulder Exercises—Elbow Exercises—The Movements of the Hands and Fingers—Balance Exercises—Knee and Ankle Exercises—The Foot—Walking, Running and Jumping.

There are two kinds of muscles which have a different structure, and separate and distinct functions.

The one kind is found in the walls of the hollow internal organs, such as the stomach and intestines, and in the arteries. It is not under the control of the will, and is therefore called *involuntary* muscle. As it is not striped it is also spoken of as smooth, plain, unstriped or unstriated muscle.

The second kind, by which the limbs are moved, is under the control of the will, and is for this reason called *voluntary*; as it is marked by cross stripes it is also known as striated muscle.

INVOLUNTARY MUSCLE.

Involuntary Muscle consists of long flattish cells, pointed at both ends. Each cell is about $\frac{1}{600}$ inch long, and has a long oval nucleus, the cell substance being enclosed in a delicate sheath. The cells are united to each other by a cementing substance.

VOLUNTARY MUSCLE.

Structure and Properties.

Voluntary muscle consists of fibres which are long in proportion to their thickness; they are about $\frac{1}{500}$ inch across, and an inch, or two, or even three, long. Each fibre has a delicate sheath and

tapers at each end, being united to the fibre above and below by a cementing substance. The sheath of the last fibres blends with the connective tissue fibres of the tendon. The true contractile muscle substance contained within the sheath has one or more nuclei, and is marked by alternate stripes of light and dark. The capillary vessels, which are very numerous, lie between the fibres outside the sheaths, and form a network with long meshes. A minute nerve enters each fibre, and ends in a mass of nucleated protoplasm in actual contact with the contractile substance of the muscle. When a muscle dies it becomes rigid, a condition called rigor mortis. This is due to a kind of clotting of the contractile substance, and in fact, closely resembles the coagulation of the blood.

Chemical Constitution.

Muscle consists of a special proteid with much water; about one-fifth of its weight is proteid, almost all the rest is water. It is, however, important to remember that it contains a little carbohydrate, about five times as much as blood.

The fibres of a muscle are bound together by connective tissue into bundles, which vary very much in size in different muscles, and the whole muscle is enclosed in a fibrous sheath.

Physical Properties: Contractility.

A muscle is extensible, that is to say it can, like a piece of india-rubber, be stretched beyond its normal length. It is also, like india-rubber elastic, that is to say it returns to it normal length when the stretching ceases. But like other living tissues, living muscle can be stimulated to act; and a muscle when stimulated contracts, each fibre becoming shorter and thicker. Normally a muscle is stimulated by impulses reaching it through the nerves, from the brain and spinal cord. But it can be stimulated also by electric currents, or by a blow. The contraction produced by the will through the nerves is stronger than that caused in any other way.

The strength of a muscle depends upon its thickness; the thicker it is the greater the force it can exert. The strength of a thick muscle is greater than that of a thin, but this has nothing to do with length, for if a long muscle is of the same thickness as a short muscle its strength is the same.

If a muscle is made to contract against an increasing resistance, the strength it exerts up to a certain point increases; but if the resistance is so greatly increased that it cannot be overcome by the greatest strength the muscle can exert, it, as it were, gives up the struggle, and the amount of force it exerts diminishes.

The amount of work done by a muscle is estimated by measuring the weight it can lift through a given height. If a pound is lifted a foot the amount of work done is said to be a foot-pound, or if a kilogram is lifted a meter the work done is called a kilogram-meter. The work done by the body, as a whole, can be measured in the same way. It is usual in estimating large amounts of work to take the average work done by one horse as a unit: 1 horse power. A labourer at ordinary work, or a man walking at a moderate pace, does about one-eighth of this. In violent exercise a great deal more work is done in the same time; a bicycle racer does about five times as much in a given time as a man walking, and, if in good training, can keep it up for many hours together. If still more work is done in a given time, the effort cannot be long continued; a short distance runner is estimated to do ten or twelve times as much work as a man walking at a moderate pace, but he cannot keep up the effort for more than one or two hundred yards.

As already said, a muscle when it contracts becomes thicker and shorter. This change in form is attended by certain other changes:

1. When a muscle contracts, the circulation through it is quickened; four or five times as much blood leaves it by the veins. But in spite of more rapid circulation this blood is darker, it contains less oxygen and more carbon dioxide than the blood from resting muscle. Active muscle then consumes more oxygen, and produces more carbon dioxide than resting muscle. This is the fundamental fact about chemical changes occurring in a muscle when it works, and affords a clue to the whole physiology of exercise.

2. A contracting muscle is slightly warmer than a resting muscle; this is to be expected, remembering the much larger production of energy. A working is warmer than a resting limb, owing partly to this production of heat in the muscular substance, and partly to the increased rapidity of the circulation.

3. Resting muscle has a neutral or faintly akaline reaction to litmus paper; acting muscle is acid, owing to the production of

phosphoric and other acids. At the same time, certain waste substances containing nitrogen are formed, the most important of which is urea (p. 95). Certain of these acids and nitrogenous bodies, conveniently spoken of as fatigue products, are poisonous (toxic), and if present in muscle beyond a certain proportion arrest its action.

4. The carbo-hydrates stored in muscle during rest are used up during contraction, and the muscles also withdraw some sugar from the blood.

During rest, muscle absorbs oxygen and stores up force-producing material. During activity, it uses up the force-producing material and excretes carbon dioxide. The carbon dioxide produced by muscular action is quickly got rid of by the lungs, the urea and toxic fatigue products much more slowly, chiefly by the kidneys.

THE VOLUNTARY MUSCLES.

As has been pointed out in the chapter on the brain, consciousness knows nothing of individual muscles. We will to make a certain movement, not to contract a particular muscle. It is seldom that any movement, even the most simple, is performed by a single muscle. We are conscious of the wish to make a movement, we are conscious that it is being made; but the selection and co-ordination of the action of the muscles by which it is made, is carried out below the level of consciousness, probably in the grey matter of the spinal cord. A minute knowledge of the anatomy of the muscles of the limbs and trunk is not necessary to a teacher of physical exercises, but it is undoubtedly advantageous to have a general idea of the position and action of the principal muscles.

The voluntary muscles for the most part pass over a joint from one bone to another. When they contract the joint is moved. In order that the movement shall be accomplished regularly and efficiently, one or other bone must be fixed. It is usual and convenient to speak of the point of attachment of a muscle to the upper bone as the point from which it arises, or its origin; and that to the lower, and usually more moveable bone, as its insertion.

The voluntary muscles are in pairs, that is to say, there are corresponding muscles in the right and left arm, and right and left leg, and on the two sides of the trunk.

The number of different muscles to which anatomists have given

names is about 240, but in the following account technicalities will be as far as possible avoided, and the muscles will be considered rather from the point of view of the movements they produce than of their anatomical relations, although something must be said about the latter. The greater the student's knowledge of anatomy, the more easily will he grasp the way in which the movements of the body are produced, and the more thoroughly will he be able to understand what are the best exercises for developing the whole muscular system symmetrically. Much may be learnt by visiting an anatomical museum, such as that of the Royal College of Surgeons in London, or those belonging to the universities or large colleges in other centres. These museums are not, as a rule, open without restriction to the public, but a student who explains the reason for seeking admission will find that not only will no obstacle be put in his or her way, but the authorities will be ready to give a great deal of assistance.

Next to actual dissecting, the best way to gain an accurate knowledge of anatomy is to make free-hand drawings from dissected specimens. But a great deal may be learnt from observation of the living body. The position and action of nearly every muscle of the upper limb, for instance, can be learnt by watching the movements of the arm and forearm. In fact, the most instructive scientific investigations on the action of muscles have been made in this way. Even if the student has the opportunity of examining dissected specimens, the study of the actual movements ought not to be neglected.

A muscle which bends a joint is called a flexor; one which straightens or stretches it an extensor. A muscle which moves a joint so as to bring the moveable bone nearer the middle line of the body, bringing the arm across the chest for instance, is called an adductor; one which carries it away from the middle line an abductor. Muscles that cause a bone to revolve on its axis, or rotate, are called rotators of the joint at which the movement occurs.

Most muscles end in a sinew or tendon formed of strong, tough, fibrous tissue. The tendons have various forms; some, as those of the fingers and toes, are long, more or less round cords; others are flat bands, others again are broad sheets, thin but tough.

Usually a muscle, either by itself or its tendon, passes from one bone to another over one joint. But it may originate from one bone, and its tendon may pass over two or three joints, to be inserted into a bone beyond. For instance, the tendons of the long muscles which bend the fingers, called the long flexors, pass over the wrist joint and the next two joints beyond, and are inserted into the last two bones of the fingers. Ordinarily when these muscles contract, the wrist and all the finger joints are bent; but it will be found that the fingers can be bent at the joint, between the first and second bones, without bending the wrist or the metatarsal joints, and that these last can be bent without bending the wrist. It is evident, therefore, that there must be some mechanism which can, when necessary, prevent the long flexors from bending the wrist and metatarsal joints. Now if the movement is made, we shall be conscious of a certain sense of effort in the back of the arm, and the muscles there, which are extensors of the wrist and fingers, can in fact be felt to contract. The extensor muscles then have come into action to control, and at certain joints to oppose and neutralise, the action of the flexor muscles. It is most important to grasp the full significance of this, because it involves a principle which applies to almost every voluntary movement and muscle; it is not limited to muscles whose tendons pass over more than one joint.

When, in performing any movement a muscle contracts, the muscle which produces movement in the opposite direction, commonly called the opposing muscle or antagonist, contracts slightly also. For instance, when the elbow is bent by the contraction of the flexor muscles of that joint, the extensor muscle contracts slightly at the same time, regulating the bending so that it is not a sudden jerk, but a regular and steady, though it may be a very rapid, movement. In the same way when the elbow is straightened by the extensor muscle, the flexor muscles act slightly to regulate the movement. This is what happens when the arm is moved simply, or in a fine movement; when a weight is lifted, or when a movement is made against resistance of any kind, the antagonists act at the beginning of the movement, but when the resistance encountered is considerable they relax, to enable the chief muscles of the movement to act alone. One reason why an ac-

customed movement is performed with more ease and precision is, that this adjustment between the two sets of muscles is carried out more rapidly and certainly.

Exercises which cause breathlessness are usually classed as violent, those which do not as moderate or gentle. Running is a violent exercise, walking is moderate or gentle, according to the pace. Moderate exercise, if long enough continued, may produce more general fatigue than violent exercise taken for a short time. A difficult exercise, or feat of strength, will quickly produce fatigue in the muscles specially used. In moderate exercise also, as for instance walking, the fatigue produced is at first mainly local, that is to say, it is the muscles most used in the exercise which become fatigued. If a man climbs up a ladder in the ordinary way on hands and feet, he does a certain amount of work but experiences no fatigue. If he climbs up the ladder by hanging on the rungs with his hands, he does the same amount of work, lifts his body through the same height, but the sensation of fatigue in the muscles of the arms and hands will be severe. Though the amount of work done be the same, it is done at a great disadvantage by the small muscles of the arms and hands, instead of by the large muscles of the hip.

We must distinguish between the quantity of work done, and the difficulty of performing some particular exercise or feat of strength. To hold a bar out with the arm extended is difficult, and the muscles of the upper limb quickly become fatigued, but much more work is done, more force expended, in a game or in walking.

Physical Exercises.

Children and young animals, when allowed absolute liberty, are almost always in movement except during sleep; movement is necessary for proper growth and development, and a sedentary life has an injurious influence on health and normal growth. Exercise improves the nutrition, not only of the muscles themselves, but of all the other organs; it stimulates the action of the lungs, increasing the intake of oxygen and the output of carbon dioxide; it accelerates the action of the heart, and in this way, and by hastening the passage of blood through the muscles, aids the circulation; indirectly it favours the digestion, improves the appetite and the

nutrition of the nervous system, and quickens the operations of the mind.

A muscle not sufficiently used wastes: take for example the shrunken condition of all the muscles of a patient confined to bed for a length of time, and the wasting of any particular limb which may have been kept in a splint. With gradual exercise the muscles grow again and the natural form of the limb is restored. During the growing period in childhood, muscular action profoundly influences the development of the bones. The bones of a child are constantly growing in length and thickness, and they are, as it were, moulded by healthy muscular action. If, then, the muscles are feeble and little used, the bones tend to be thin, slender, and ill developed, and yield more readily to any cause tending to produce deformity. Well regulated exercise stimulates the growth of the bones, makes them stronger, ensures that they assume their normal form, and preserves the symmetry of the limbs and trunk.

Long hours of confinement in school, unless counteracted by a wise system of physical exercises regularly carried out, may have an injurious effect upon the muscles and bones. In leaning over desks, the chest becomes contracted, circulation and respiration is impeded, the spine curved, sight injured and headaches acquired (Plate XVI.). The aim of ideal physical culture is to undo the evils of school life; to expand the chest and straighten the figure. The muscular system should be evenly and harmoniously developed, perfect balance being aimed at; one part of the body must not be overworked at the expense of another, and in every movement consideration must be given to the heart and lungs. The moral side of the question must also be remembered: the brain should be enabled to govern the body, by having absolute control over it. Therefore physical culture is not to be regarded merely in the light of enjoyment or recreation, as a display of meaningless movements executed by children whose brains are left behind in the school-room; on the contrary, in taking a new exercise the teacher will clearly explain its mechanism to the class.

The exercises in the *Syllabus of Physical Exercises for Use in Elementary Schools* (1904) are based upon the Swedish system, a system above all others which must be well taught by energetic and competent teachers, because it is so apt to become monotonous.

The first position in a Swedish exercise is the ideal one, and the child is expected to return to it after each exercise. Slouching is incompatible with personal dignity, and a body well under control increases mental force, gives self-confidence, alertness, decision and concentration.

The exercises in the Syllabus are classified, according to their effect, as nutritive, corrective and control exercises.

Nutritive Exercises.

These are intended to improve the respiration and circulation. Both of these are quickly and powerfully affected by massive movements, more especially of the lower limbs, in which the whole body and muscular structure of the body take part. Good examples of such movements are to be found in the natural games of children, running, leaping, skipping. This is why it is so essential that a time should be set apart for play and romping. A break of five or ten minutes between each lesson is advisable, to change the ideas, to rest certain parts of the brain, and to call others into activity. Free running about and games in the school-yard are most beneficial, but where this is not possible a few swift massive movements, taken if necessary standing up beside the desks, will cure inattention by stimulating the circulation and respiration. The exercises selected must be well known and simple, to be done for the purpose of nutrition mechanically and without mental effort.

Breathing Exercises.

Exercises of the upper limbs, by bringing into play the muscles concerned in the process of respiration, tend to develop the chest capacity and to encourage the healthy action of the lungs. The vital measurement is not that of the chest capacity alone, but of the difference between the full and empty chest. In breathing exercises with or without exercises of the upper limbs, it is important that the power of emptying the chest should be cultivated.

The importance to health of correct breathing is not generally understood; there is only one correct way of breathing, and that is through the nose. The nose is supplied with a filtering apparatus, which cleanses and warms the air as it passes through to the lungs. Breathed in through the mouth, the cold air with all its impurities

goes straight to the lungs, causes colds and admits the microbes of disease into the system.

In breathing, the position of the body must be studied. The shoulders should be thrown back and held in position, the blades forced downwards towards the waist and inwards towards each other (Plate XVI., D). In this position the ribs in front are stretched, the chest expanded and the tendency to rounded shoulders checked. Many people develop a humpy, round-shouldered appearance, because in breathing the shoulders are allowed to move instead of being kept steadily in position, the lungs being thus encouraged to expand at the back instead of in the front of the chest. In learning breathing exercises it is of great assistance to press the hands firmly on the hips and then raise the chest only, imagining that the thorax is being pulled high into air by a string. This exercise, in which the teacher should join for the sake of her own physique, may be done sitting, lying down or standing, frequently, and for a very short time: never in bad air. If giddiness is felt the exercise should be stopped, but when the children get accustomed to breathing properly the giddiness passes off.

Breathlessness is the result of an accumulation of carbon dioxide gas in the lungs. It is often caused by incorrect breathing, and may be cured by attention to the above rules. The teacher will understand that mouth breathers, or children with adenoid growths, cannot breathe through the nose, and must receive medical treatment. When the child is enabled to breathe through the nose its power of attention, which will have been interfered with by the growths, will be restored. Educationally this is of great importance, and from a health point of view diminishes the risk of contracting infectious diseases.

It will be well to teach children breathing exercises as soon as they are admitted into the infants' department. This serves a double purpose, for it enables teachers to recognise sufferers from throat and nose complaints, and to obtain for them early treatment by causing them to be examined by the medical officer.

Corrective Exercises.

These exercises aim at the correction of bodily defects which school life tends to aggravate. Thus a simple exercise, such as heels

raising (38), if not too often repeated at any one time, counteracts the tendency to flat foot by strengthening the muscles and stimulating the growth of the ligaments which support the arch of the foot; and head and trunk backward bending (69 and 71) sets up a child inclined to stoop over its desk, a position which produces myopia, for the eye should never be less than twelve inches distant from the work. Bad habits are so soon acquired, and are so difficult of eradication that too much trouble cannot be taken to secure habitually good positions. This applies especially to the younger children.

Control Exercises.

These have their principal effect upon the nervous system and upon the control exercised by the nerve centres over the muscles. The nerve centres have to be educated, and the process is slow. Balance exercises are types of control exercises—*e.g.*, learning to bicycle or to skate means the exerting of will power in order to control the muscles and nerve centres. To a nervous person bicycling, or skating often depends much more upon moral courage than physical skill, as is proved by examples of good riders who cannot mount or dismount a bicycle without assistance. Control exercises then are important, as enabling us to oblige our body to bend to our will, just as we might curb a strange body. This power of control helps people to pass through the crises of life with a courage and calmness impossible to those who have not acquired self-control.

Educational Effect.

All exercises at a certain stage and in a certain degree have an educational effect. The exercises must first be mastered and then always be done intelligently and as perfectly as possible. In order to attain this result it is necessary to go through an educational process in which the will and intelligence are involved, with necessarily a corresponding education of the nerve centres and the brain. The syllabus points out that while a new exercise is being learnt, concentration of mind and effort of will are necessary, and a certain degree of fatigue naturally accompanies the earlier performances; but in time the exercise becomes practically an automatic act. Its value as an educational exercise then ceases and

it becomes purely nutritive. The same exercise may be educational if taken by beginners, and nutritive when performed by scholars who can do it automatically; upon this distinction must depend the time and the manner in which the exercises should be chosen. If the educational element is to be kept up, new exercises will have to be introduced from time to time; but inasmuch as this necessitates brain work and concentration, they should only take up part of the lesson. A higher degree of accuracy and precision will be expected with increasing practice and advancing years.

Rapid and vigorous exercises powerfully stimulate the respiration and circulation and should be taken for short periods only, followed by exercises which tend to quiet the pulse and respiration. Vigorous exercises are obviously more needed in those schools in which opportunities for stimulating games and natural exercise are restricted, and where the children have not long distances to walk to the school. Vigorous exercises, however, increase the demand for nutriment, and it is the teacher's duty to see that underfed or weakly children are not injured by too much physical work. Such cases should be excluded and reported to the Education Authority.

For children under seven natural play is the best exercise: but breathing exercises should be done several times a day for short periods, and the greatest attention paid to correct positions. Free-arm drawing standing at a blackboard is a valuable exercise, while all fine work involving the small muscles, such as pricking cards, sewing, and writing on lined paper, is injurious for children under seven years.

It is essential that exercises be done in loose clothing, and women teachers should point out to the elder girls the danger of wearing tight steel boned corsets, and also speak to them of other matters regarding their health. Special gymnasium shoes ought to be provided, as many of the exercises, such as heels raising, lose their value by being done in old boots down at the heel and often many sizes too large. Teachers should be able to give the lessons without reference to the syllabus: a good plan is to cause new exercises to be performed by a smart scholar placed in front of the class. The words of command must be given in a clear precise manner, and the lesson conducted with energy and purpose.

In the following pages, the most important exercises in the

Syllabus are considered, in relation to the muscles or groups of muscles called into action in their performance.

Standing.

The Syllabus recognises two attitudes in standing, "2.—The position of attention," and "3.—Standing at Ease."

The voluntary muscles are at rest only when the body is lying flat in bed. To sit upright calls many muscles into action (Plate XVI.), to stand many more; standing at attention is more fatiguing than walking.

In considering how the erect posture is maintained, we have to take into account two factors, the straightening and stiffening of the spinal column and lower limbs, and the position of the centre of gravity of the body.

In standing, the muscles of the neck, back, loins, hips, knees, ankles and toes are all in action, to keep the body rigid from head to feet. The centre of gravity of the whole body in the adult is about $1\frac{1}{2}$ inches below the top of the sacrum. Now a perpendicular line dropped from this when the body is erect, touches the ground a little in front of the ankles, so that there is a constant tendency for the body to fall forward, and this must be counteracted by muscular action. But if the muscles which pull back the body acted alone, the body would fall backward, or, if the body were inclined to one side, then it would fall to that side, so that in standing erect the muscles which pull the body forward, as well as those which pull it to either side, must be in action in order to maintain the balance.

In an infant or young child, owing to its relatively large head and short legs the centre of gravity is higher, so that the tendency to fall forward, and therefore the difficulty of maintaining the balance, is greater. This to a very large extent accounts for the comparatively late period at which an infant learns to walk, as compared with the young of four-footed animals. A kitten or a puppy manages to walk, in a feeble and uncertain way it is true, when only a few days old. The uncertainty is not due to any great difficulty about its centre of gravity; that is somewhere about the middle of its body, and a perpendicular dropped from it touches the ground between the hind legs and the fore; it is due to the fact that its nervous system and muscles have not yet been educated to

make the necessary movements. The child has to overcome this difficulty also, and it is the greater, because to walk erect demands a more nicely adjusted balance than to walk on four feet.

The Position of Attention.

The Syllabus directs that in the position of attention:

> The body and head must be held erect.
> The knees well braced back, the heels closed, and the toes turned out.
> The weight of the body is to be on the fore part of the feet.

These are the essential points in the position, but in addition the chest is to be expanded, the shoulders squared to the front and slightly drawn back, and the chin drawn in. The upper limbs must hang easily.

If we consider this position we shall see that the whole spine must be made rigid and the head balanced upon it; that the hips, knees, and ankles must be made taut, and that the balance of the whole body must be so adjusted, that the centre of gravity is over the front part of the feet. As the heels are close together the basis of support is narrow, so that the balance must be nicely adjusted.

The spinal column is made rigid by the combined action of the muscles at the back and front, by which it is straightened or bent.

The chief muscle by which the spine is straightened or extended is the erector spinæ, a long, strong muscle which runs the whole length of the back, from hip to head on each side. It arises by a strong, flat tendon from the spinous processes of the lumbar and sacral vertebræ and the crest of the hip bone; its bulk fills up the broad groove seen in the skeleton, between the spines and the backward curve of the ribs. It is inserted by muscular slips one above the other into all the vertebræ, into some of the ribs, and into the skull at the back part of the mastoid process.

Beneath the erector spinæ in the loin is a short, thick, oblong muscle, called from its shape the quadratus lumborum, and between the two muscles is a strong thick band of fibrous tissue, giving strength to the back wall of the abdomen.

The front wall of the abdomen is formed, partly by muscle and partly by sheets of strong connective tissue. Three of these muscles,

the straight muscle and the two oblique muscles, are the chief flexors of the spine. The straight muscles, one on each side, are flat and long, extending on each side of the middle line along the whole front of the abdomen from the fifth, sixth, and seventh rib-cartilages to the pubis. The outer oblique is a strong muscle, arising from the lower ribs, and passing obliquely downwards and forwards to a strong sheet of fibrous and elastic tissue over the front of the abdomen, into which the muscle of the opposite side is inserted also. The inner oblique muscle arises below, from the strong band of connective tissue in the fold of the groin, called Poupart's ligament, and from the crest of the hip bone; it spreads out obliquely upwards, to end in a sheet of fibro-elastic tissue, attached to the lower ribs and common to the muscles of the two sides, which helps to give strength to the front wall of the abdomen. These abdominal muscles have already been mentioned as among those which act in deep respiration, pulling down the ribs and compressing the abdominal organs, and so forcing the diaphragm upwards in expiration; when the chest is fixed, however, they bend the spine forward. This explains the object of the instruction, that in standing at attention the chest is to be expanded and the shoulders squared and drawn back.

The syllabus directs the head to be held erect and the chin slightly drawn in. Now the head is so poised upon the atlas that its centre of gravity is in front of its point of support; the head therefore has a tendency to fall forward, but this is prevented by slight contraction of the muscles of the neck, maintained by the nerve centres which control them. When this control is suspended, as for instance when a person falls asleep in a chair, the head nods forward until the chin rests on the chest. The head is held erect, partly by the erectors of the spine, which, as has been said, are inserted into the mastoid processes, and partly by a set of small deeply placed muscles which arise from the cervical vertebræ, and pass upwards to be inserted into the occiput.

The muscles which brace the hips, knees and ankles will be more conveniently considered in connection with exercises which cause movements at these joints.

The position of standing at attention brings a great number of muscles into action, and is said to be more fatiguing than walking;

the syllabus points out that it is a position of strain, and scholars should never be kept in it for more than half a minute at a time. It is not a natural position, owing especially to the narrowness of the base upon which the body rests, the two feet brought close together. This is shown by the much greater ease of the next position.

The two starting positions, "*14.—Hips firm*," and "*15.—Neck rest*," are really positions of attention, modified by raising the hands to the hips and to the back of the neck, respectively, movements which will be considered in connexion with the upper limbs.

Sitting.—It will be observed that in sitting erect, all the muscles which brace the spine and keep the head upright must be in action, so that in this posture only, the muscles of the hips and lower limbs are resting (Plate XVI., C, D).

Standing at Ease.

In this position the same muscles are concerned as in standing at attention, but they are under much less strain; as the feet are a foot's length apart, and as the weight of the body rests equally on the two feet, the basis of support is much wider and the balance can be maintained with much less effort. The weight of the body is transmitted through the hips and the bones of the lower limb to the feet; a line dropped from the centre of gravity to the ground will pass inside the hip, knee and ankle joints, and fall well within the basis of support. The activity required from the muscles in standing at ease is, therefore, very much less than in standing at attention, in fact it is believed that the muscles of the spine are in a condition of vigilant repose, ready to correct any sway backward or forward or to either side, rather than in a state of actual contraction.

Head Exercises.

The movements of the head take place chiefly at the joints between the occiput and the atlas, and between the atlas and the axis. The joint between the occiput and the atlas permits of movement of the head backwards and forwards, extension and flexion; a very slight amount of rotation is allowed also, and this is the most stable position of the joint. In natural attitudes the head is turned a little to one side or the other; to hold the head direct to the front is not a natural attitude, and requires a certain slight amount of

muscular action. The movement of rotation of the head takes place mainly at the joint between the atlas and axis, the former revolving round the pivot formed by the projecting body of the latter. The vertebræ of the neck, moving a little the one upon the other, allow of a certain amount of backward and forward movement and rotation of the head.

69. *Head Backward Bending.*—The head is moved backwards by the upper part of the trapezius muscle mentioned in connexion with the shoulder, and by small muscles passing from the upper part of the spine to the occiput.

The head is raised again and bent forward by the sterno-mastoid muscles, the prominent muscles on either side of the neck, which descend obliquely from the mastoid processes of the temporal bone, to the top of the sternum and inner end of the collar bone (Plate XI., 4).

78. *Head Turning.*

> Hips firm : *One;* keeping the body erect and steady, turn the head slowly to the left as far as possible, looking in that direction. *Two;* turn the head slowly to its former position.

The head is turned, that is to say rotated to one side or the other, chiefly by the sterno-mastoid muscles. The movement is assisted and regulated by the trapezius muscle at the back of the neck, and by some of the deeper muscles of the neck already referred to.

Trunk Exercises.

70. *Trunk forward bending.*

> Hips firm : *One;* bend the trunk slowly forward from the hips, chest fully expanded, head kept slightly back, eyes directed forward. *Two;* slowly resume the starting position.

71. *Trunk backward bending.*

> Hips firm : *One;* keeping the knees straight, bend the trunk backwards slowly, the head commencing the movement, the whole of the spine being arched, eyes directed upward. *Two;* by reversing the former movement, raise the trunk and head slowly to their former position.

These two exercises must be considered together, for the same muscles are concerned. Their study is interesting, because the

muscular action which takes place illustrates a general principle, to which reference has already been made. In every slow movement made in the direction of gravity, that is to say, where the weight of the body or limb favours the movement, the muscles in the direction of the movement relax, while the antagonists, those muscles which would produce movement in the opposite direction, contract and support the part. The movement of bending the trunk forward is started by the muscles in the front of the abdomen, which have been referred to above as flexors of the spine; but as soon as the trunk has begun to bend they relax, and the muscles of the back, erectors of the spine, contract and gradually "let out the weight of the trunk in the same way as a heavy weight is slowly lowered to the ground by a crane."

In fact, these muscles come into action as soon as the centre of gravity is altered, even though only by a movement of the head. In exercise 69, "Head backward bending," as soon as the head is moved backward, the straight muscles in the front of the abdomen contract, to check any movement of the trunk backward; and in a corresponding way, if the head be bent forward, the erector muscles of the back contract to prevent the spine from bending. The action, which is involuntary, takes place instantaneously and can easily be felt by putting the hands on the muscles in the middle of the back, just above the hips.

When the movements are made against resistance, as for instance, when the trunk is bent against resistance in pushing, then the muscles act differently: those which bend the trunk continue to contract strongly, while the muscles of the back relax.

83. *Trunk sideways bending.*

> Hips firm: *One;* bend slowly to the left, shoulders square to the front, eyes directed to the front, head held in position relative to the shoulders. *Two;* raise the trunk slowly to the upright position.

The muscles concerned in the movements are the same as those that bend and stretch the trunk. In bending to the left, the straight muscle of the front of the left side of the abdomen, and the erectors of the spine on that side start the movement; but as soon as the centre of gravity has been displaced to the left they relax, and the

PLATE XI.

THE CHIEF MUSCLES OF BODY. (*A reduced reproduction of a drawing in "Fabrica Humani Corporis," by And. Vesalius.*)

MUSCLES: 1, Temporal; 2, Masseter, one of the chief Muscles of Mastication; 3, Buccinator Muscle of the Cheek; 4, Sterno-mastoid; 5, Trapezius; 6, Latissimus Dorsi; 7, Serratus Magnus; 8, Great Pectoral; 9, Scapular Muscles; 10, Deltoid; 11, Biceps; 12, Triceps; 13, Supinator Longus; 14, Extensor of Thumb; 15, Extensor of Index Finger; 16, Extensors of other Fingers; 17, External Oblique; 18, Gluteus; 19, Quadriceps; 20, Hamstrings; 21, Adductors of Thigh; 22, Calf Muscles.

23, Annular Ligament of Ankle; 24, Popliteal Space; 25, Annular Ligament of Wrist.

Chief Muscles of Body.

corresponding muscles on the right side contract and let the weight of the body gradually down towards the left, on the same principle as has been stated when explaining forward or backward bending. The trunk is raised again to the upright position by the straight muscle and the erector muscle of the right side. When sideways bending is done against resistance, the straight abdominal muscle, and the erector of the spine on the side to which the trunk is bent, contract forcibly, and are assisted by the other muscles of the front of the abdomen on that side.

Shoulder Exercises.

The shoulder is a very moveable joint, in fact the most moveable in the body. The extreme mobility of the upper limb, and the fineness and precision of the movements which are possible, distinguish man and the apes from other animals. The bones of the fore-leg of a horse are on the same general plan as those of the upper limb of man; but we have only to contrast the limited movements possible in a horse with the wide range in man, to see how the skeleton is adapted to it purpose. But the movements at the shoulder joint are not so free as might appear at first sight. If, standing in front of a person we grasp the shoulder gently, putting the fingers on the blade bone, and tell him to raise the arm, we shall find that until the arm reaches the horizontal the bone does not move; but when the arm is lifted higher the bone begins to rotate, until, when the arm is above the head, the angle of the scapula points outwards, and in a thin person with lax muscles sticks out prominently. When the arm is lowered the scapula moves back again; when the arm is carried forward the scapula rotates in a similar way.

50. *Arms sideways raising.*

> *One;* raise the arms sideways in line with the shoulders, fingers extended, and palms downward. *Two;* lower the arms to the sides.

51. *Arms sideways and upwards raising.*

> *One;* as in 50. *Two;* keeping the arms straight and well back, turn the palms smartly upward, and immediately raise the arms until they are vertical above the shoulders. *Three;* lower the arms sideways to the level of the shoulders,

keeping the palms upward and arms well drawn back. *Four;* turn the palms smartly downward and lower the arms to the sides. After some practice the sideways and upwards raising should be done in one continuous movement.

The muscle which raises the arm to the horizontal level is a strong, short, triangular muscle called the deltoid (Plate XI., 10), from its resemblance in shape to the Greek letter delta (Δ). Its broad end is attached to the most prominent part of the shoulder, back and front; its pointed end has a strong, short tendon which is inserted into the outer side of the humerus, a little above the middle. When the lifting of the arm is carried beyond the horizontal level, the movement is taken up by a large muscle, the great serratus, which arises by slips from the eight upper ribs (Plate XI., 7), and passes backwards close to the chest and beneath the scapula, to be inserted into the under surface of that bone at the back part. When it contracts, it pulls forward the angle of the scapula as described above.

The movement of lifting the arm to the horizontal, and above the head, is regulated by a number of muscles, of which the trapezius and great pectoral are the most important.

The trapezius (Plate XI., 5) is a large, flat, triangular muscle covering the back of the shoulder, immediately under the skin. The muscles of the two sides together have the shape of a monk's cowl hanging down. It arises from the occiput and the middle line of the spine, as low as the last dorsal vertebra, and the fibres converge towards the shoulder, the upper bundle descending to be inserted into the outer part of the collar bone, the middle passing horizontally to the acromion process and spine of the scapula, and the lower ascending to the root of the spine of that bone. The lower part of the muscle steadies or fixes the angle of the scapula; the upper part is the chief muscle by which the shoulders are shrugged.

The arm which has has been raised is brought down again to the side by its own weight, and the movement is regulated, or if it be resisted, is carried out by a number of muscles acting in combination, of which the latissimus dorsi and the great pectoral are the most powerful.

The latissimus dorsi (Plate XI., 6) is another large flat muscle,

which arises from a broad, flat, fibrous expansion, attached to the lower part of the spine and the back part of the iliac crest. Its fibres run upwards round the side of the chest, and end in a tendon which is inserted into the front of the humerus. It not only pulls down the elevated arm, but if its action is completed, it carries the arm behind the back with the palm backward, the whole movement being nearly that of the arm in swimming.

The great pectoral muscle, pectoralis major, is the strong, flat, thick muscle on the front of the chest, which forms the front fold of the armpit (Plate XI., 8). It consists of two parts, upper and lower, and these act independently in certain movements. The upper part arises from the inner part of the front of the collar bone, the lower from the sternum and the cartilages of the upper six ribs; the fibres converge to a tendon inserted into a ridge on the front of the humerus. The upper part helps to raise the humerus, the lower to depress it. Both together carry the arm forward across the chest, as in folding the arms.

The triceps muscle, at the back of the arm, also takes part in bringing down the shoulder against resistance.

49. *Arms forward raising.*

> *One;* raise the arms forward to the level of the shoulders, palms inward, elbows and fingers straight, arms parallel. *Two;* lower the arms to the sides.

59. *Arms forward and upward raising.*

> *One;* raise the arms forward, as in 49, and continue the movement upward till the arms are in the upward stretch position. *Two;* lower the arms forward and downward to the sides, keeping the arms parallel and the palms inward.

The arm is raised forward to the level of the shoulder by the front part of the deltoid muscle, and the upper part of the great pectoral, assisted by the biceps (p. 195). The arm is raised upward above the head by the rotation of the blade bone, produced by the contraction of the great serratus, in the same way as in 51. This muscle can also pull the whole blade bone directly forward, and with it the arm. If the arm be held straight to the front, it is possible, by an effort of the will, to push the hand two or three inches more forward, and with the hand on the scapula this can be

PLATE XII.

SKIAGRAM OF THE ELBOW OF A CHILD AGED 10 YEARS. (*From an original Skiagram taken in the Radiographic Department, St. Thomas's Hospital, London.*)

H, Humerus; **U**, Ulna; **R**, Radius. Note the epiphysis of the olecranon process of the ulna.

Skiagram of Child's Elbow.

felt to be due to that bone being jerked forward. This movement, much used in boxing and in fencing, is produced by the serratus magnus; it acts powerfully also in pushing.

Elbow Exercises.

The elbow is a hinge joint (Plate XII.), allowing the backward and forward movements of bending and stretching, but it is not a simple hinge joint, since it permits movements by which the hand is turned palm downwards (pronation), or back downwards (supination).

In many of the elbow exercises in the Syllabus, in fact in nearly all, the muscles which move that joint are worked in conjunction with the muscles of the shoulder joint. Exercise 28, rather oddly termed "arms downward stretching," since the first movement is upward bending, may be taken as the basis for a brief explanation of the way in which movements at this joint are produced. The Syllabus also calls the forearm the lower arm, although the former word is a good old English term, and is generally understood.

The chief bender of the elbow is the biceps, so called because it has two heads, *bis* twice, *caput* head; it is the prominent muscle in the front of the arm (Plate XI., 11). Both heads arise by tendons from the blade bone; they unite in a thick spindle-shaped muscular mass, which ends in a short tendon inserted into the back part of the tuberosity on the inner side of the radius, just below its head. Its action is reinforced by a short thick muscle which lies under it. This muscle, the anterior brachial muscle, brachialis anticus, arises from the front of the lower part of the humerus, and is inserted into the front of the ulna, just below its head.

The opposing muscle, that which stretches the elbow and regulates its bending is the triceps, the large muscle of the back of the arm (Plate XI., 12). It owes its name to the fact that it has three heads: two of these arise from the back of the humerus, the third long or middle head from the neck of the blade bone. The three parts of the muscle end in a common tendon, inserted into the back of the olecranon process of the ulna. The triceps, as a whole, is the stretcher of the elbow; but the middle head, springing from the scapula has another action also, which affords an illustration of how the contraction of one muscle during a movement, may call into action also a set of muscles with which it might not at first sight

appear to have any connexion. The long head of the triceps, as has been said, is one of the muscles that helps to pull down the arm after it has been raised, but as it cannot contract without extending the elbow, the muscles which bend the elbow must act to neutralise the stretching action of the triceps.

Hands Turning (Pronation and Supination).

The exercise "hands turning" finds a place, rather oddly, in the Syllabus under shoulder exercises, with which it has nothing to do.

51. *Hands turning.*

> Hands turning may be practised when the scholars are in the arms sideway raise position. On the command, "hands turn," the palms will be turned upward or downward, as the case may be.

This is not an important exercise in itself, but it is worthy of some study, because the power of turning the hands up or down, or to any intermediate position is of immense importance to man in all kinds of work, from digging to watch making. It will be convenient to use the recognised terms: pronation for the position with the palms down, from *pronus*, lying flat on the face, and supination for the position with the back down, from *supinus*, lying on the back.

Supination, that is, turning the palm of the hand upwards, is performed chiefly by the biceps; but as the action of that muscle is mainly to bend the elbow, the triceps must come into play to counteract the flexion; supination is assisted by the extensors of the wrist. Pronation, that is, turning the palm of the hand downwards, is carried out chiefly by the pronator teres, a short and not very strong muscle, which arises from the inner side of the humerus just above the elbow, and passes obliquely across the joint, to be inserted into the outer side of the radius about half way down. It is assisted by the muscles which bend the wrist.

The Hand and Wrist.

The wrist is formed of small bones, arranged in two rows with joints between: the upper row articulates with the radius and ulna, the lower with the bones of the palm (Plate XIII.). The small

bones are bound together by strong ligaments, in such a way that they make a shallow arch with the concavity on the palm side: the whole arrangement gives elasticity. Encircling the wrist is a fibrous band, the annular ligament, with compartments through which the tendons of the wrist and long finger muscles work (Plate XI., 25).

The movements at the wrist are bending and backward stretching, and from side to side; bending is freer than stretching, and the movement inwards, with the palm up, freer than outwards. The finger joints are all hinge joints (Plate XIII.).

The muscles which move the wrist and fingers and thumb are very numerous, as might be expected, remembering the great variety of movements which the hand can perform.

There are two sets of muscles: the long in the forearm, with tendons which run through the compartments in the annular ligament, and the short in the palm. The long muscles at the front of the forearm are benders, those at the back extensors.

Of the muscles in front of the forearm, the most important are the two which bend the fingers. One of these ends in four tendons, inserted into the second bone of each of the four fingers, and its action can be shown by bending the second joint of the fingers without bending the last; this can easily be done. The other likewise ends in four tendons, which are inserted into the third and last bones of the fingers. It will be found that it is not possible to bend the last joint of the fingers without bending the second, but the action of this muscle may be shown by holding the second joint with the other hand, when it will be found that the last joint can be bent. These muscles also bend the hand at the wrist, their action being assisted by two other muscles, which are inserted into the wrist end of the palm bones of the first and little fingers. The antagonists of these muscles, those which straighten the fingers, are at the back of the forearm. There is one large muscle ending in four tendons, one for each finger, a small muscle especially for the little finger, and another strong muscle for the first finger. The greater freedom and accuracy of movement of the first finger, often called the index or indicator finger, is well known, and is mainly due to the existence of this special muscle. In the same way the greater freedom of the little, as compared with the second and third fingers, is partly

PLATE XIII.

SKIAGRAM OF THE WRIST AND HAND OF A CHILD AGED 10 YEARS. (*From an original Skiagram taken in the Radiographic Department, St. Thomas's Hospital, London.*)

Note the epiphyses at the lower ends of the radius (**R**) and ulna (**U**) and of the metacarpal bones (**M**) of the fingers, and at the upper ends of the phalangeal bones (**P**) of the thumb and fingers. The metacarpal bone of the thumb, it will be seen, has an epiphysis at both ends. The wrist bones are still not completely ossified.

Plate XIII.

Skiagram of Child's Hand.

due to its special muscle; there are also muscles for straightening the wrist, corresponding to those which bend it. Between the bones of the palm are two sets of small muscles; one set spreads the fingers out while the other draws them together again.

The great mobility of the thumb, the ease and certainty with which it may be put into a great variety of positions, and the force with which its movements can be executed, must strike anyone who gives the matter a moment's consideration: it is the most characteristic property of the hand of man, in whom it is much more highly developed even than in the highest apes.

The thumb is moved by no less than eight muscles, four long and four short. The four long muscles are in the forearm and have tendons which run through the compartments in the annular ligament of the wrist. One of these in front bends the thumb, its tendon being inserted into the last bone. At the back of the forearm are three muscles for straightening the thumb (Plate XI., 14): one inserted into its metacarpal bone, one into the next bone, and the third into the last. The four short muscles form the ball of the thumb: one of them draws it away from the fingers, another draws it towards the fingers, another bends it, while the fourth carries it across the palm. In the movement of opposition, by which the thumb is brought so as to face any one of the fingers, the last three muscles act together. The little finger has also three small palm muscles, which form the smaller ball on the other side of the hand, corresponding to the ball of the thumb; they pull the little finger and the inner side of the palm inwards, as in the movement commonly called hollowing the palm. It will be observed, that these movements of the thumb and little finger are favoured by the freedom of movement at the joints between their metacarpal bones and the wrist, which is much greater than in the corresponding joints of the first, second and third fingers.

Balance Exercises.

The exercises under this head in the *Syllabus* are chiefly for the lower limbs, but it will not be forgotten that all balance exercises call into action the muscles of the trunk, by which the spine and head are held upright.

The hip is a ball and socket joint in which the round head of the

PLATE XIV.

Skiagram of the Knee of a Child aged 10 years. (*From an original Skiagram taken in the Radiographic Department, St. Thomas's Hospital, London.*)

It shows the lower end of the thigh bone (T), the upper ends of the tibia (S) and fibula (F), and the knee-cap (P), seen from the inner side. The knee is partly flexed, and it will be seen that the head of the tibia has glided backward on the end of the thigh bone, and is opposite the back part of the joint surface. Note the epiphyses (E, E, E) of the femur, tibia and fibula.

Plate XIV.

Skiagram of the Knee of a Child.

thigh bone is received into the cup-shaped cavity, acetabulum, of the hip bone. The joint is enclosed by a strong, but not very tight bag-like ligament, and there is a small, round ligament, which joins the centre of the round head of the thigh bone to the edge of the cavity in the acetabulum. The movements at the hip joint are free, but bending, which is stopped only by the thigh coming in contact with the abdomen, is freer than stretching. Sideways stretching is also free, and the thigh can be moved inwards with much force. The thigh can also be turned, rotated, in or out.

The knee (Plate XIV.) is a hinge joint of complicated pattern, as is explained elsewhere. When fully stretched it is, as it were locked, but when bent it can be rotated through about the eighth of a circle.

45. *Knee raising.*

> Hips firm. *One;* bend the left knee upward until the thigh is at right angles with the body, lower leg hanging straight downward from the knee, toe pointing downward as far as possible, body erect. *Two;* lower the leg to its original position.

48. *Knee raising and backward stretching.*

> Hips firm. *One;* as in 45. *Two;* keeping the body erect, slowly stretch the leg and foot to the rear, the toe pointing to the ground. *Three;* resume position one. *Four;* as in 45.

Exercise 45 is really hip bending, and exercise 48 is hip bending followed by hip stretching *plus* knee stretching.

The chief bender of the hip is a long, fleshy muscle, the psoas, inside the abdomen. It arises from the front of the spine in the loins, and from the inside surface of the hip bone, and ends in a short, thick tendon inserted into the small trochanter of the thigh bone. It bends the thigh on the body, or the body on the thigh according to circumstances. Thus, it is one of the muscles which raises the trunk into a sitting posture after lying down; in this it is assisted by the muscles of the front of the abdomen. It bends the thigh on the trunk in walking, running, or jumping.

The chief muscle which carries the thigh back in backward stretching (48), is the large thick four-sided muscle, the gluteus, which

forms the prominence of the buttock on each side (Plate XI., 18). It arises from the back of the hip bone and sacrum; its fibres pass obliquely downwards to the outer side of the thigh, and are fixed partly into a strong sheet of fibrous tissue, covering the muscles of the thigh in this place, and partly into the outer part of the thigh bone. It is assisted by certain muscles of the thigh, especially the great adductor (p. 205). The gluteus is the chief muscle for carrying the thigh backward, as in walking, but especially in going up hill; it is one of the most important muscles in jumping, since by forcibly straightening the trunk on the thigh it gives power to the spring.

47. *Knee raising and forward stretching.*

> Hips firm. *One;* as in 45. *Two;* keeping the thigh raised as much as possible, stretch the leg and foot forward. *Three;* resume position one. *Four;* lower the leg to its original position.

Here the movements added to Exercise 45 are the stretching and bending of the knee. The knee is straightened by the great muscle in the front of the thigh called quadriceps, because it has four heads which end in a strong tendon inserted into the kneecap (Plate XI., 19). Three of the heads arise from the front of the thigh bone, but the fourth is placed in front of the others, and arises from the hip bone; it can be felt firmly contracted when this exercise is performed; it helps to bend the thigh when the knee is straight, as in this exercise. This muscle is in action with every step in walking and in marking time. In this exercise (47) the knee is bent again by the weight of the leg, regulated by the gentle action of the same muscle that straightens it. When the knee is bent against resistance, or when the weight of the leg has to be lifted, as in bending the knee while the weight of the body is carried by the other limb, a movement performed with every step in walking and still more completely in running, then the force required is supplied chiefly by a set of muscles at the back of the thigh, called the hamstrings. They are three long muscles (Plate XI., 20) which arise from the ischial tuberosity of the hip bone and the back of the thigh bone, and are inserted one into the head of the fibula, and two into the head of the tibia. Their tendons

form the upper sides of the lozenge shaped space at the back of the knee, where the popliteal artery can be felt beating (Plate XI., 24). Their action is assisted by the more superficial of the two large muscles of the calf.

38. *Heels raising.*

> Hips firm. *One;* keeping the body erect, legs straight and heels together, raise the heels quickly as high as possible. *Two;* keeping the knees straight, lower the heels slowly.

The movement takes place at the ankle, a simple hinge joint allowing of little or no movement from side to side, and at the joints between the long bones (metatarsal) of the foot and the toes.

The heels are raised mainly by the powerful calf muscles, of which there are two; the more superficial (Plate XI., 22) arises from the lower end of the thigh bone, the deeper from the back of the two leg bones, both ending in the strong tendon at the back of the heel, called the tendon of Achilles, because it was by this that his mother held Achilles when she dipped him in the river Styx, to render him invulnerable.

44. *Leg sideways raising.*

> Hips firm. *One;* raise the leg sideways to the left as high as possible without unduly disturbing the erect position of the body. *Two;* lower the leg to its original position.

39. *Knees bending and stretching.*

> Hips firm. *One;* as in 38 (Heels Raising). *Two;* keeping the trunk and head erect and heels together, bend the knees slowly outward until the thigh and lower leg form a right angle. *Three;* straighten the knees slowly, keeping the heels raised. *Four;* as in 38. (Later the older boys may receive the command *Knees Full—Bend*, when the body will be lowered as far as possible.)

The leg is stretched sideways, chiefly by two small gluteus muscles, which arise beneath the great gluteus muscle from the surface of the hip bone, and are inserted into the great trochanter of the thigh bone. The leg is lowered again to its original position in Exercise 44 by its own weight, controlled by slight contraction of these two muscles which let it down regularly and gently. If the leg has to be brought down against resistance, as in Exercise 39,

PLATE XV.

Dissection of the Sole of the Foot to Shew the Short Muscles and the Tendons of the Long Muscles. (*Photograph of a specimen in the Museum of the Royal College of Surgeons of England.*)

Dissection of Sole of Foot.

where the legs bearing the weight of the body have to be held in the sideways position, the adductor muscles, which form the strong fleshy mass at the inner side of the thigh (Plate XI., 21), contract. They arise from the front of the hip bone near the middle line and spread out like a fan, to be inserted into the whole length of the back of the thigh bone.

The Foot.

The foot is a double arch, that is to say, it is arched in its length (instep) and also from side to side in front, along the ball of the toes. The piers of the arch of the instep are the heel and the ball of the toes, and in standing, the greater part of the weight of the body rests on the heel and the ball of the great toe. The small bones of the foot, the tarsal bones, which form the heel and instep, are firmly bound together by ligaments. The longer bones of the sole of the foot, the metatarsal bones, which articulate with the front of the bones of the instep, have rather more play. A strong ligament passes from the heel forward in the sole, to the roots of the five toes, and helps to support the arch against a shock. The long muscles, the tendons of which wind behind the ankle on its inner and outer side (Plate XV.), and the long muscles, the tendons of which pass over the front of the ankle to the toes, also help the foot to withstand a shock, as in jumping. The whole arrangement gives strength and elasticity.

The Heel Raising Exercise (38) is not very suitable to young, growing children whose bones are not yet fully ossified, as it tends to spread the front part of the foot. Long standing has the same effect and may crush the arch of the instep, producing flat foot. This deformity is very common in children who carry weights, especially in girls who have to look after a baby and to do hard housework at an early age. It is produced also in boys who begin young a trade, such as that of a baker, which involves much standing about. It is not advisable to keep a class standing long in the same attitude, even at ease. If for any reason an exercise lesson has to be stopped for a time, it is better to dismiss the class and let the children play, summoning them again when the class can be resumed.

The number and arrangement of the muscles of the foot have a general resemblance to those of the hand. There are two sets, long muscles in the leg, and short muscles in the sole of the foot, while

over the front of the ankle is a strong bandlike ligament with compartments for the different tendons, as at the wrist. (Plate XI., 23).

There are four ankle muscles, three in front and one behind. The muscle at the back is strong, and its tendon winds behind the inner ankle, to be inserted into the inner side of the instep. One of the muscles in front ends in a tendon which passes through a compartment in the front ligament, and is also inserted into the inner side of the instep. These two muscles acting together, turn the sole inwards, and help to sustain the arch of the instep against a shock. The other two muscles have long tendons which hook round the back of the outer ankle; the tendon of one goes to the outer side of the foot, that of the other crosses the sole, to be inserted into the inner side of the metatarsal bone of the great toe. (Plate XV.). This muscle strengthens the transverse, side to side, arch of the front of the foot, when it is pressed upon by the weight of the body on the toes, as for instance in Exercise 39, or in alighting from a jump.

There are long muscles behind the leg for bending the four small toes, and in front for stretching them. There are also separate long muscles for stretching the great toe and the little toe.

In the sole of the foot are special muscles for the great toe and little toe, besides two muscles which assist in bending all the small toes. There are also, as in the palm of the hand, small muscles between the metatarsal bones for spreading the toes.

Marching.

In walking, each leg alternately supports the weight of the body, while the other is swinging forward, the supporting leg doing the work of that particular step. At the beginning of a step the supporting leg is drawn a little forward, the knee is straightened to its full extent, and the heel is raised until the weight of the body rests first on the ball of the toes, and finally on the great toe. At the same time the hip has been tilted up a little on the other side, a movement which assists in lifting the toes of the other foot from the ground; the knee of the swinging leg is then bent, the whole limb is swung forward as far in front of the supporting foot as it was formerly behind it, and the foot is placed flat upon the ground, with the knee very slightly bent. The knee is then completely straightened, and this leg in its turn becomes the supporting leg,

while the other begins to swing. A common fault in walking is to bring the foot to the ground with the knee too much bent, and never to straighten it completely. It is doubtless for this reason that the Syllabus directs that "both knees must be kept straight, except while the leg is being carried from the rear to the front, when the knee must necessarily be a little bent to enable the foot to clear the ground."

In running there is a moment when both legs are off the ground, as is seen in instantaneous photographs. The active, or supporting leg, comes to the ground rather more bent at the knee than in walking, and it is mainly the sudden forcible straightening of the knee which gives the body the push or jerk forward observed in running.

Jumping.

103. *Upward jumping.*

> *One;* heels raise. *Two;* knees bend. *Three;* stretch the knees quickly and spring upward from the ground, straighttening the whole body in so doing and coming down on the toes with the knees well out, and the body in full balance. The head and body should be erect during the whole movement.

Jumping calls into action a great number of muscles. The actual force for the upward or forward jump, is supplied by the muscles which straighten the hip, knee and ankle; but at the same time, all the muscles which strengthen and bend the spine and hold the head erect, must be in concerted action to maintain the balance of the body, especially on alighting again. In jumping forward, the direction is given to the body mainly by the calf muscles. In a vigorous jump, the instruction to keep the head and body erect during the whole movement is not practicable, as the spine is always bent a little at the highest point of the jump.

IX.—THE CHILD,

AND THE DISEASES OF SCHOOL LIFE.

The Normal Healthy Child; its Aspects, Characteristics and Rate of Growth—Defective Children; Mentally Defective, Physically Defective—Backward Children—Diseases in School Life—Nature of Contagion and Infection—Bacteria—Conditions of their Growth, Temperature, Light and Food—Cultivation of Bacteria—Classification—Action and Reaction—Prevention of Infection in Schools—School Closure—Exclusion of Infective Children and Contacts—Influenza—Scarlet Fever—Diphtheria—Small-Pox—Tuberculosis—Disinfection.

The Child.

An elementary school is usually intended to meet the requirements, not of one particular social class, but of a whole district, consequently children of all grades of physical and mental capacity must be received into it. It will be the teacher's business to form an idea of the average capacity of the scholars in the school, and to frame a programme suited to their mental powers. The cases of children who fall decidedly below this average will call for special investigation; it will therefore be necessary to distinguish between the normal and the abnormal child.

The healthy child holds its head well up, its back straight and the shoulders well thrown back; the skin of the face is firm, the complexion clear, the lips red, the eyes bright and the hair glossy; it moves quickly and energetically, and is full of activity. The limbs feel firm, and there is no excess of fat. Such a child will not far depart from the normal height and weight for its age, shown in the following table.

Height and Weight of Children from 5 to 15 Years of Age.

AGE LAST BIRTHDAY.	HEIGHT WITHOUT SHOES IN INCHES.		WEIGHT WITH CLOTHES IN LBS.		RATIO : WEIGHT DIVIDED BY HEIGHT.	
	M.	F.	M.	F.	M.	F.
5-6	41·0	40·8	39·9	39·6	·97	·97
6	44·0	42·6	44·4	42·4	1·01	1·00
7	46·0	44·5	49·7	46·7	1·08	1·05
8	47·1	46·6	54·9	52·2	1·16	1·12
9	49·7	48·7	60·4	55·5	1·22	1·14
10	51·8	51·1	67·5	62·0	1·30	1·21
11	53·5	53·1	72·0	68·1	1·35	1·28
12	55·0	55·7	76·7	76·4	1·39	1·37
13	56·9	57·8	82·6	87·0	1·45	1·51
14	59·3	59·8	92·0	96·7	1·55	1·62
15	62·2	60·9	102·7	104·8	1·65	1·72

As will be seen, boys on an average grow more rapidly than girls from five to ten years of age, while from ten to fifteen the reverse is the case.

The ill-nourished child has a slouching walk, stooping shoulders, bent knees, and a general appearance of slackness ; the muscles are flabby and the face dull and pale.

There is also the *nervous* type with thin, fine limbs, eager to excel both in lessons and in games, its characteristic restless activity. Such a child is easily fatigued, excitable, sleeps badly, and is liable to break down under an amount of work which children of more stable nervous organisation can easily stand.

Defective Children.

Crippled children are often mentally bright, but until lately, when unable to go to school, their education has been necessarily neglected. Thanks to the initiative of Mrs. Humphry Ward special arrangements have recently been made in some towns for conveying such children to school, or for teaching them in the hospitals to which they are admitted for the treatment of their deformities.

Blind children are of course not fit to be taught in ordinary classes, and those with serious defects of vision, which cannot be

corrected by glasses, ought also to be taught in specia classes. Bad vision, due to errors of refraction, may be corrected by suitable glasses prescribed by an oculist, and such children should be re-admitted to the ordinary classes. This subject is fully discussed in the section on vision (p. 159).

Deafness is a common cause of backwardness; it varies very much in degree from mere dulness and slowness of hearing, to complete inability to hear the speaking voice. A child born quite deaf, or who becomes deaf before it has learnt to speak, is also dumb and can only be taught in a special class for deaf-mutes. They are now instructed on the lip-reading system, being trained to imitate the teacher's mode of breathing and the movements of her lips in speaking. Those who become deaf after they have learnt to speak, quickly lose the faculty unless carefully trained in special classes; their recollection of speech, and any remains of hearing, greatly help in their education. Excluding these, there remains a proportion of children, probably from 3 to 5 per cent., whose progress is seriously retarded by defective hearing. The causes of this partial deafness, their prevention, and the means available for improving the hearing, are considered in the section on hearing (p. 166).

Nervous disorders of various types may render children unfit to benefit by lessons in ordinary classes. Among these, special attention may be directed to *chorea*, or *St. Vitus' dance*, which is very common at about ten or twelve years of age, especially in girls. In a well marked case the movements are violent, any movement attempted being performed in a wild, ungainly way; the child is unable to speak distinctly, and it is impossible to expect it to attend school. In very slight cases it may seem to be merely perverse and clumsy, and may be injured by being rebuked and compelled to go on working. If a child, previously neat and well-mannered, begins to drop things and to make faces, it should be sent for examination to the medical officer, as it may be in an early stage of chorea Some children, both boys and girls, have tricks of movement, such as blinking the eyes, twitching the mouth, and twisting the head, which a little resemble chorea but really have nothing to do with it; such habit-spasms may be checked by good discipline, but it should be gentle and discriminating, for the habit may be so established that the child may be unconscious of it.

Diphtheria is followed in a considerable number of cases by a special form of paralysis that may be extensive, or affect only a few nerves, more particularly those of the eye. Diphtheria is sometimes so mild as to be unrecognised, and any child, whether it has recently had a sore throat or not, noticed to be squinting or to have difficulty in reading, should be referred for medical examination.

Defective and backward children. Even in healthy children the rate of mental development varies to a certain extent; in normal ones this difficulty can be met, by varying the age at which they are passed from a lower to a higher standard. There is, however, a certain proportion of children with whom it is impossible to deal in this way, because they suffer from physical or mental defects that prevent their efficient education in a class of normal children, and necessitate a special system of teaching. It is estimated that at least ten per cent. of the scholars on the rolls in London are, for reasons either of a permanent or temporary nature, unfit for ordinary elementary school classes.

Speech defects are particularly apt to occur in children of nervous temperament; among these may be mentioned stammering, the confusion of vowel sounds and the mispronunciation and clipping of words. Children may be helped to overcome stammering by being excused from reading or reciting aloud, and by being gently encouraged to answer questions slowly and distinctly. Occasionally children are encountered who, though otherwise intelligent, owing to a special defect in the speech centres of the brain, cannot be taught to recognise written words, to write from dictation, or to speak (aphasia). Such children are very apt to be reckoned imbeciles; but this is a serious error, and under proper tuition in special classes, though the defect can never be actually cured, they may be made useful members of Society. Mirror writing, that is writing backward so that the writing can be read in a looking-glass, is rather common, and is evidence of mental instability, calling for special care in education.

Mentally defective children. None of the children properly classified under this head are fit for instruction in ordinary elementary schools: but the nature and degree of the mental defect varies. The lowest grade are imbeciles, and should be placed in

imbecile asylums; above these are the feeble-minded, capable of benefitting by instruction in special classes. A special Act of Parliament (Defective and Epileptic Children Act, 1899), exists for the benefit of these. Most education authorities in the larger centres now recognise the obligation to provide special classes for feeble-minded children, and the number of classes is increasing annually. It is the duty of teachers to co-operate, by calling the attention of the medical officers to individual children who appear dull or feeble-minded, so that he may recommend them for admission to special classes, or for treatment.

Epileptic children are a great difficulty, for epilepsy varies very much in severity. In an average case, the patient has a fit of general convulsions with loss of consciousness at irregular intervals, perhaps once a month, or once a week or oftener. Such children should have special treatment, preferably in an epileptic colony. The accommodation, however, provided in these colonies is at present inadequate, and if the epilepsy is not severe, pressure may be brought to bear upon managers and teachers to keep such children at school. In some cases the fits only occur at long intervals of several months, and it may be possible for the parents to recognise, from the altered appearance or demeanour of the child, that a fit is coming on, and to keep it away from school for a time. In London and many other places it is customary to require such children to attend ordinary schools, but the teacher should constantly watch them, as a fit in school is distressing and injurious to the other children. Epilepsy, even when the attacks are infrequent, is sometimes accompanied by distinct mental deficiency, and such cases are not fit to be in ordinary classes. There is a very mild form of epilepsy in which there may be no obvious convulsions, and the loss of consciousness is only momentary. Sometimes the child immediately after the seizure behaves in an odd way; it gets up for instance, and walks round the room, or suddenly hits another child, and pays no attention when rebuked. In such cases if it had been carefully watched, some slight seizure, a momentary turning up of the eyes, a sudden stoppage in speaking or writing, might have been observed to precede the odd behaviour. All such cases should be at once referred to the medical officer.

Anæmia is very common in town-bred children; the face is

pale though it flushes easily, and the lips have not a natural rosy-red colour; the child's muscles are flabby, while it is easily fatigued and apt to be listless. Anæmia is a sign of malnutrition, and is usually caused by under feeding and sleeping, and working in ill-ventilated rooms.

After the list of definite disorders and diseases causing unfitness is exhausted, there still remains a considerable number of children who cannot derive full benefit from school teaching, owing to general debility, languor and want of physical and mental energy. The causes of this debility are numerous; it may be due to a delicate constitution little able to resist fatigue, it may be due to insufficient food or clothing, or both; to bad surroundings in the home, insufficient fresh air, sunshine and exercise, or to slow convalescence from scarlet fever, measles, whooping cough or diphtheria. Debilitated children should not be excluded from school, but an experienced teacher will show special consideration towards them, helping by kindness and indulgence to a healthier tone of mind and body. If the cause is want of food, and if no system of feeding underfed children has been organised in connection with the school, it may be possible to obtain assistance for the child through some benevolent agency.

It would be well if teachers would use their influence in favour of the establishment of holiday colonies, such as have existed for many years in most other countries. Elementary school children, during the summer vacation, are either boarded out in country cottages or sent to special camps, or temporary homes in the country, where they are well and simply fed, and spend most of their time in the open air. A beginning has been made in this country by boarding out a few children, and by the annual organisation of boys' camps at the sea-side, but the principle ought to be greatly extended, and much more should be done for girls, who at present fare very badly.

A capable teacher will aim at the highest physical and intellectual standard in his school. The responsibility and anxiety of sifting out the fit from the unfit will be very great, but with assistance sometimes from the parents this can be accomplished. The removal of those children unable to benefit by the teaching in an ordinary school to a more suitable environment, will not only be

of benefit to them, but will enable the teacher to attain for normal scholars the highest possible standard.

Acute Infectious Diseases in School Life.

Education is much interfered with by periodical outbreaks of acute infectious diseases in schools. These epidemics not only endanger the lives and after-health of children actually attacked, but also interfere with the education of others. To the teacher falls the duty of looking out for cases likely to require examination by the medical officer. He must therefore have some practical knowledge of the symptoms of certain infectious diseases; he must understand how they are conveyed and how they spread if precautionary measures are not at once taken.

Of the diseases from which mankind suffers a very large portion is due to infection, that is to say, to the entrance into the body of parasites; this is especially true of the period of childhood. These parasites are vegetable or animal, and may be classified as follows:

Vegetable	Bacteria producing typhoid fever, diphtheria, tuberculosis, etc. Fungi producing ringworm, etc.
Animal	Blood parasites producing malaria and sleeping sickness. Worms infesting the intestines chiefly, but also other organs.

In each disease the infection is distinct: thus the germ of measles could not produce small-pox nor could the germ of whooping-cough cause scarlet fever.

Not every person who is exposed to infection contracts it. In a district where typhoid fever is rife only some suffer from it, and everybody who lives in a large town is frequently exposed to the infection of tuberculosis, yet only some contract it. Everyone has a certain power of resistance to infection, and this is greater at one time than another, depending in part at least, on the general state of health at the moment when infection is encountered. Thus a man may resist the infection of typhoid fever during one epidemic and succumb to it during another. Again, a person who has once suffered from an acute infectious disease, such as small-pox, is little liable to be infected again. Such a person is said to be immune from the disease. This condition of immunity may be produced artificially in the case of certain diseases, as by vaccination against small-pox, the injection of anti-toxic serum against diphtheria, etc.

Before commencing to study the diseases common to childhood, it is first of all necessary to understand the difference between the terms contagion and infection.

Contagion is the transmission of a disease from the sick to the healthy, either by direct contact of the part affected, or through the medium of the excretions or exhalations of the body.

Infection is contamination by morbific particles, carried by water or scattered into the air from the clothing or books of the sick child, and breathed in by the healthy who may become infected. In coughing and sneezing liquid matter from the air passages is sprayed into the atmosphere, and even in speaking droplets of saliva are disseminated through the air of rooms, to a distance of as much as forty feet. There is a third way in which an infectious disease may be disseminated, and that is by a child apparently healthy, who has taken into its system germs which do it, personally, no harm because it is not susceptible, but which can set up disease in another child who is susceptible and predisposed. Direct relations with the patient are therefore not necessary for the transmission of disease: owing to this not being understood the word contagious is often misapplied.

Infection then may be conveyed from a person suffering from a disease either directly by personal contact, or indirectly (1) through a third person as just explained, (2) by clothes, linen, furniture or books, (3) through the air, (4) by water, (5) from the soil. Finally, certain diseases are produced by bacteria which appear to be present everywhere.

In the case of certain of the acute infectious diseases, small-pox, scarlet fever, measles and whooping cough for instance, the infective agent has not been discovered. As it can increase and multiply, we must conclude that it is a living thing, and as the infection appears to spread in the same way as infection known to be due to bacteria, and can be destroyed by the same agencies, heat, etc., as bacteria, it is generally assumed that these diseases are caused by bacteria as yet unrecognised.

In the case of certain other acute infectious diseases, the infective agent is known to be a bacterium which can be cultivated in the manner described below, but there is a great deal of difference in the ease with which these different bacteria maintain their existence

independently of human beings, or at least of warm-blooded animals. The bacterium of pneumonia appears to be almost ubiquitous; the tetanus bacillus exists very commonly in the soil, and the plague bacillus can live and probably multiply for long periods, in granaries and dirty houses. The typhoid bacillus can live, and presumably multiply for some considerable time in well water and in soil, and the influenza bacillus has some means of maintaining itself independently. The diphtheria bacillus is not capable of maintaining an independent existence for long outside the body, and the same is true of the tubercle bacillus.

The power of a bacterium to grow and multiply, and to produce disease in the body, is spoken of as virulence. The intensity of the virulence of a particular kind of bacterium may vary very much; for example, a chain coccus which, when it finds its way into a wound, usually produces only more or less local inflammation, is sometimes exceedingly virulent, causing acute general blood poisoning in a few hours. Occasionally a bacterium, the colon bacillus, ordinarily a harmless possibly a useful inhabitant of the intestines, becomes virulent producing severe inflammation, abcesses, and even general blood poisoning.

Bacteria.

Bacteria, which belong to the vegetable kingdom, swarm everywhere on the earth, and in water. They are so small that they can only be seen through a powerful microscope; but their effects are easily seen. If some clear broth is left in a glass in a warm room for a day or two, three changes may be noted: it has become turbid, it has a disagreeable smell, and a sour, bad taste. The bacteria in the glass, or falling from the air, or both, have grown so fast that their number makes the broth turbid, and while growing they have changed the meat juices into bad-smelling, sour-tasting substances which are poisonous. There are other bacteria which, if they get into the digestive canal, or into the blood or tissues, actually grow there and cause disease: this is what happens in typhoid fever, blood-poisoning or abcess. But there are others quite harmless, and, in their proper place, essential to man; they grow, for instance, in soil, and help to make it fertile. Plants would not live in soil that contained no bacteria. Our aim, therefore, must be to destroy

the deadly bacteria, and to exclude the poison producers from food and drink. Cleanliness is the great enemy of all kinds of bacteria.

Of the numerous different kinds known to bacteriologists, only a few produce disease: some which cause disease in animals are harmless to man, and vice versa. In the scheme of nature, the true work of bacteria would seem to be the decomposition of animal and vegetable refuse, breaking down complex organic substances into simpler bodies, which are diffused through the air, or sink into the soil to be utilised again by plants.

Conditions of growth.

In order that they may be able to multiply freely, bacteria must have food and moisture, and must be kept at a suitable temperature.

Temperature. For every species of bacterium there is a temperature at which it grows best. For those which habitually exist and multiply in the animal body, including the disease producing ones, the best temperature is usually about that of the body, with a range of about from 95° to 102° F. For most of the ordinary bacteria of decomposition, summer temperature is the best, 68° to 75° F., but in manure heaps there are species which grow best at a temperature as high as 150° F. Most bacteria will still grow, but less freely, at temperatures a good deal higher or lower than that which is best for them, but under these unnatural conditions they often lose some of their properties. Cold, even extreme cold, though it stops the growth of bacteria, does not easily kill them; the cholera microbe, for instance, can be subjected to a temperature many degrees below freezing, and will grow again when the temperature is raised to that which suits it best. The same is true of heat up to a certain point; a temperature a good deal higher than that at which a bacterium ceases to be able to grow will not kill it, for it will begin to grow again at a temperature suited to it. For every bacterium, however, there is a temperature beyond which it cannot long survive, and at a still higher temperature it is killed very quickly. The typhoid bacillus, for example, is killed if kept at 140° F. for half an hour, and in two or three minutes at 212° F., the boiling point of water. Spores will survive a temperature which kills the bacillus from which they are derived. The bacillus of anthrax, a disease of cattle by which man is sometimes infected, known as wool

sorters' disease, is killed after a short time by a temperature of 140° F., but its spores can be boiled for five minutes without being killed. The tubercle bacillus is very resistant to heat. If dry, it can survive exposure to the temperature of boiling water for an hour; if moist, however, it is usually killed in an hour by a temperature of 158° F. In fact, it rather resembles a spore in these respects.

Light. Most bacteria are killed in a few hours by exposure to direct sunlight: the typhoid bacillus, for instance, is killed in about an hour and a half. Even diffused daylight is unfavourable to the growth of most bacteria, although they will survive for a long time.

Food. Bacteria, like all other living things, require food in order to grow and multiply. In nature, most of them occur in decomposing animal or vegetable matter; they attack and, as it were digest it, thus supplying themselves with the nitrogenous and carbohydrate material they require for building up their own substance. Most bacteria also require free access to oxygen, that is to say, they grow best when freely exposed to air. Others can grow also in an atmosphere which contains no oxygen, although they grow equally well or better in the air. Others again, of which the bacillus of tetanus, lock-jaw, may be mentioned as an example, will not grow if oxygen is present in the atmosphere. It must be supposed that such bacilli obtain any oxygen they need for their own growth, by splitting up the organic matter in which they grow.

Moisture is necessary for the growth of bacteria, and most of them die when dried. There are some very important exceptions, however. Tubercle bacilli can survive even when they have been quite dried up for two or three months. Spores are also much more resistant to drying than bacilli; those of anthrax will survive dry for a year, and immediately begin to grow when placed in a suitable medium.

Many bacteria, probably all, produce during their growth substances, unfavourable to their continued multiplication. So that after a time a particular bacterium will cease to grow in a particular place; this occurs before the food is exhausted. Finally it dies, unless it has the power of forming spores. But the substances unfavourable to its own growth may have no such effect on another kind of bacterium, and in fact, it is probable that the com-

plete decomposition of dead animal and vegetable matter is brought about by a series of different bacteria, which succeed each other in a more or less regular order. Bacteria, deprived of all nutriment, finally die; in distilled water the typhoid bacillus dies out in about three weeks.

Experimental Cultivation of Bacteria.

Bacteria are studied by growing them either in broth, or more conveniently on jelly or a slice of potato. Most fluids and other substances which the bacteriologist has to examine, contain many different sorts of bacteria, and the great progress made in bacteriology followed the invention of a method of separating them. To do this a nutrient jelly is prepared with meat juice or peptone, and a little is poured into a series of test tubes. The tubes are then lightly plugged with cotton wool, which acts as a germ-filter preventing any bacteria either getting into the tube from the air, or out of the tube into the air. The tubes and their contained jelly are then sterilised by heat; the jelly will now keep unaltered for an indefinite time, if evaporation is prevented, either by storing the tubes in a moist place, or by putting an indiarubber cap over the mouth of the each. Tubes thus prepared are commonly called culture tubes.

If a specimen of drinking water, which may contain perhaps half a dozen kinds of bacteria is to be examined, the bacteriologist melts the nutrient jelly in one of the tubes by warming it; he then takes a fine platinum wire mounted in a glass handle, passes it through the flame of a Bunsen gas burner or a spirit lamp, so as to destroy any bacteria which may have been adhering to it, and, after it has cooled, dips it into the water, removes the cotton wool plug from the culture tube, stirs the platinum wire in the jelly, withdraws the wire and replaces the plug. He has ready a flat covered glass dish, which has been sterilised by heat; removing the cover and withdrawing the plug from the culture tube, he pours the jelly on to the bottom of the dish, where it sets in a short time. The object of all this is to get the bacteria, in the minute drop of water which adhered to the platinum wire, distributed as evenly as possible through the relatively large bulk of jelly. The dish is then put in a warm room, to encourage the growth of any bacteria which were present in the water. If the experiment is properly made, and if

the number to begin with was not too numerous, each single bacterium will begin to grow separately, and in the course of a few hours or days, as the case may be, will have developed so rapidly as to form a mass visible to the naked eye; the mass is called a colony.

The form and appearance of a colony of one bacterium differs more or less from that of others; some liquify the jelly forming little moist pits, which may be round or irregular, opaque or transparent; others grow through the jelly without liquifying it; others form little projections or mounds, which again may be transparent or opaque, round or irregular, white or more or less coloured. The colonies grow at different rates, some bacteria being more vigorous, or finding the temperature or the nutriment in the jelly more suitable to them, and finally these quick-growing colonies run into each other and overrun the slower growers. But before this happens, there is a stage when the surface of the jelly is covered by a number of detached colonies, each the offspring of a single bacterium; and it will be easy to see that the colonies differ among themselves in appearance. There may be twenty of one kind, and half a dozen of another, and one or two of another, and an experienced bacteriologist will, from long familiarity with their characters, be able to make a shrewd guess at what each is.

He next proceeds to make a pure culture of each in the following way. He takes a culture tube, without melting the jelly; he sterilises his platinum wire, touches one of the colonies in the dish with it, and either plunges it into or strokes it on the surface of the jelly, replaces the cotton wool plug, and keeps the tube at a suitable temperature. After a time, strings of colonies will be seen growing along the track the needle took; as these colonies are all the offspring of bacteria which came from a colony, itself the offspring of a single bacterium, they must all be of the same species. This is a pure culture which can be examined microscopically or chemically, or used for starting as many more pure cultures as may be desired.

The same principle is applied to the examination of organs and fluids of disease, but the composition of the nutrient material must be varied to suit the needs of the particular bacterium. The bacillus tuberculosis, for example, grows best on blood serum which has been

coagulated by heat; it requires also a high temperature. It grows slowly, but eventually forms a white, glistening, irregular mass, projecting from the surface of the coagulated serum.

Classification of Bacteria.

Three classes of bacteria are distinguished according to form (1) globular, called cocci, (2) rods, called baccilli, and (3) spirals, called spirilla.

Cocci, though all very minute and therefore called micrococci, vary in bulk: some idea of their size may perhaps be gained from the statement, that the diameter of the smallest of them is about one-fifteenth of that of a red blood corpuscle, and that twelve thousand of the largest of them placed side by side would measure about an inch. The cocci multiply by dividing into two new cocci, which usually adhere to each other. Sometimes the division takes place always in one direction, so that the cocci adhere together in chains, sometimes irregularly so that they form clusters. This difference in the way of growing has been used to make two classes of cocci: (1) the chain cocci, streptococci, and (2) the cluster cocci, staphylococci. Very few of the cocci have any power of independent motion.

Of the disease-producing micrococci, the most important are those which cause infection of wounds. They are practically ubiquitous, and among other places in which they are nearly always present is the skin, so that any wound which is not properly treated is liable to become infected with them; so long as the skin remains unbroken they do no harm. There are several different kinds; one called the golden cluster coccus, because, when cultivated on jelly or potato, it forms orange-coloured colonies.

Bacilli are round rods, the different sorts varying in length and breadth but all being very minute. Many of them have the power of independent movement, due to the presence on the surface of fine whip-like processes called flagella, *flagellum*, a little whip. The bacilli usually multiply by dividing into two, each quickly growing to the same length as the parent rod. Some of them, under certain circumstances, usually such as are not very favourable to the growth of the particular bacillus, form spores, round bodies able to resist degrees of heat or dryness that would kill the bacillus itself.

Placed again in favouring circumstances, each spore quickly grows into a bacillus and this proceeds to multiply by division.

Spirilla are so-called because, under the microscope, they appear as spirals or coils. Some are rather long, wavy threads; of these, the microbe of relapsing fever is an example; others are short, curved rods joined together, end to end, to make a wavy filament; the microbe of cholera is the best known example.

Action and Re-action.

Bacteria cause symptoms of disease, not directly by their mere presence, but indirectly by poisonous substances which they produce during their growth. These substances, called toxins, vary very much in the intensity of the poisoning they produce. The micrococci, cause of abscesses, pimples and discharging wounds, produce a toxin which, as a rule, poisons only the cells in the immediate neighbourhood. At the opposite pole is the tetanus bacillus; this multiplying slowly, perhaps in an insignificant wound, produces a toxin so intensely poisonous that the patient may seem to have taken a dose of strychnine. The diphtheria bacillus behaves n a similar way; from a small focus in the throat may be produced a toxin, so poisonous in quality and so large in quantity, as to affect the whole system in a few hours, and to produce changes in the nervous system from which the child may take months to recover.

The body, however, possesses a power of resisting infection, of destroying bacteria and of neutralising their toxins; otherwise the human race must long ago have been exterminated by its microscopic foes. This resistance is two-fold: it resides in the cells and in the fluids. The immediate result of the establishment of disease-producing bacteria, is a migration towards them of amoeboid cells, white corpuscles of the blood, and similar cells from the tissues. For the moment the conflict is between these cells and the bacteria. Doubtless nine times out of ten, or ninety-nines times out of a hundred, the cells (phagocytes) are successful; they enclose, kill and dissolve the bacteria. This is the first line of defence. Those that escape are taken up by the lymphatics and carried to the lymphatic glands, the cells of which multiply, causing some swelling of the gland (p. 47), and destroy and dissolve the bacteria. This is the second line of defence. But if the bacteria are very

numerous, or very virulent, the toxin they produce paralyses and kills the cells. Then the bacteria multiply and form their toxin, which is absorbed into the blood producing fever and other general symptoms. The presence of the toxin in the blood leads, after a varying interval, to the appearance of an antidote, the anti-toxin, which neutralises the toxin. This is the third line of defence. Eventually, if the patient is to recover, the anti-toxin is produced in sufficient quantity to neutralise the whole of the toxin, whereupon the cells gain the upper hand and destroy the bacteria, and the disease is at an end.

The resistance of the body may, however, be overcome through complications. The bacteria and the toxins of the acute infectious disease, may so weaken certain organs, that they readily become infected by one or other of the bacteria already mentioned as always present on the skin and in the intestines. For instance, the toxins of influenza, or measles, or whooping cough, may so weaken the lungs, that they become the easy prey of inflammation, and the patient is killed, partly by the general poisoning due to the primary disease, but mainly by the pneumonia. In scarlet fever, and in measles also, the toxin so lowers the vitality of the mucous membrane of the throat and ear that it readily becomes infected by micrococci, which produce more or less severe inflammation.

The Prevention of Infectious Diseases in School.

The conditions in the school-room make the spread of disease inevitable sometimes, even where the most rigorous precautions are taken.

It has been explained that the living germs of disease are so microscopically small that the finest particle of dust may contain large numbers of them. The germs, brought to school in the clothes or books of children coming from infected houses, are blown about the room, generally not too well ventilated, and breathed in by the scholars. The close contact of children sitting side by side, in all probability at dual desks, also favours the spread of infection.

Before 1891 no serious attempt was made to prevent the spread of infectious diseases in schools, but since then prophylactic measures have been more and more employed, with the result that an epidemic of disease now rarely necessitates the closure of schools.

When this has to be done the necessity can usually be traced to slow action on the part of the teacher, who destroys the *raison d'être* of closure by allowing the disease to spread through the class. Apart from the great loss of time caused to the healthy scholars by the closing of a school, it has been found impossible to prevent children of the lower classes from meeting together; if they do not go to school they will assemble in the streets. Some people consider that the danger from infection in the streets is not so great because the children are in the open air, but they are not under supervision, and this adds to the risk. As far as the chief infectious diseases are concerned, such as small-pox, diphtheria and scarlet fever, the law makes it compulsory for the parent or guardian, and medical practitioner, to notify each case to the Medical Officer of Health as soon as they become aware of its existence.

The Public Health (London) Act, 1891, (the Code regulations have since then been considerably simplified and the notification forms revised, in order to ensure the receipt of early information in regard to infection in schools, and to minimise the clerical work of the head teacher), made it compulsory for the Medical Officer of Health to send a copy of the notification relative to small-pox, diphtheria, erysipelas, cholera, membranous croup, scarlatina, scarlet fever, typhus, typhoid, enteric and relapsing fevers, to the teachers of any school attended by children from infected houses, and the head master should receive a copy of the notification certificate within twelve hours of its receipt by the Medical Officer of Health.

On receipt of the notification from the Medical Officer of Health the following action is taken:

(*a*) The Head Master sends the notice to the Head Teachers of the other departments.

(*b*) All affected children (whether suffering or coming from the home in which the disease exists), are excluded from school.

(*c*) Head Teachers of all departments forward, on the same day, the names and addresses of all children affected by the notice to the Divisional Superintendent and the Medical Officer of the Committee, on a form specially provided for the purpose.

(*d*) The notification is then filed at the school until the end of the school year.

In addition to the notifiable diseases, the following non-notifiable diseases are dangerous to school children: measles, mumps, whooping-cough and chicken-pox. If a child shows symptoms of any of these diseases or comes from a home where such a disease is known to exist:

(a) The child is excluded.

(b) The Head Teachers of the other departments are informed.

(c) The Head Teachers of all departments forward on the same day the names and addresses of all affected children to the Divisional Superintendent, Medical Officer of Health, and Medical Officer of the Board, on S.M. Form 84.

In most other towns and districts, the notification of the so-called minor infectious diseases has not been made compulsory: among these are measles, whooping-cough, chicken-pox and mumps. The teacher therefore must take prompt preventive measures to guard against an epidemic of these diseases in the schools.

Incubation Period and Prodromal Symptoms.—In every infectious desease there is an interval after infection called the incubation period, during which no symptoms are present and the patient is not infectious. After an interval, varying in each disease, the patient is attacked by the symptoms of onset. From the first moment that these occur he can spread the disease.

What often makes it hard to recognise the acute infectious diseases in the early stages, is that the preliminary, or so-called prodromal symptoms, so commonly take the form either of cold in the head or of sore throat. A cold in the head is such an every-day occurrence, that naturally a teacher would be loth to exclude every child who suffered from such symptoms: yet a cold in the head is the first symptom of measles, and constitutes its so-called catarrhal stage.

MEASLES.

Measles is a disease which has proved particularly difficult to deal with, mainly owing to the fact that it is highly infectious in the preliminary stage before the rash appears, when the child may be thought to be suffering from a common cold. The indifference with which it is regarded by the parents of the poorer classes, who look upon it as inevitable, is another difficulty to contend with: they are glad that the child should get it over while

young. This old fashioned idea clings to them, for measles used to be regarded as a slight unavoidable childish ailment. Both views are wrong: measles is not inevitable, and it is, as a rule, far more serious and fatal in young children than in older. Although the actual attack may be slight, measles is perhaps more to be dreaded than many more serious illnesses on account of the after effects, such as deafness, weak eyes and even blindness, and great physical debility.

It is therefore necessary to employ preventive measures, and in order to do this effectively the teacher must be prepared to act with promptness. Recent experience proves that closure, to be successful, must take place on the occurrence of the very first case in a susceptible class. By a susceptible class, is meant a class in which very few of the scholars have already had measles. It has been found that it is necessary to keep a record of the measles history of all children. This can only be done by the teacher, who should find out from each child on admission to the school whether it has, or has not, had measles: the record could be passed on, as the child is promoted to a fresh standard. At Woolwich, where a special study of measles has been going on for the last two or three years, the measles history of every child in the infants' departments is recorded on a separate card to be kept at school. On the back of the card the teacher fills in the measles history of the child when admitted. In the event of a subsequent attack, particulars of this are entered on the card, and it is separated from the others. The card is taken to the house, and on its reverse particulars are entered by the Medical Officer of Health or his assistant, as the result of the domiciliary enquiry.

Supposing a child to have a very bad running cold and to appear ill and heavy, the first thing the teacher does is to look up the record. If there is no evidence of a previous attack of measles, it will be well to send the child home to be watched. After about seventy-two hours the rash appears, so that even if it were only a cold in the head, the loss in school attendance would be slight. Since measles is highly infectious, from the very beginning of the running of the eyes and nose, this case, supposing it to have been measles, may have infected others. Let all subsequent cases of running cold then be sent home until it is known whether the first

child is pronounced, after seventy-two hours, to have measles. In a case of this kind prompt closure of the school, or of the class would probably check an epidemic, and should be resorted to in a susceptible class, that is to say, where few of the children have had measles. In a school two crops of measles may be expected: the seed for the first crop is the first case, which, during the catarrhal stage, infects other children near it. The seed for the second crop, usually much larger than the first, are the cases of the first crop.

The closure would be likely only to last a very short time. The incubation period of measles may be taken as twelve days, and Dr. Kerr states that often the closure of a class for a period, embracing the twelfth day after that on which the child was in school in an infectious condition, is sufficient. Hitherto closure of schools has been a sort of last resource when the epidemic had spread very much, generally after the occurrence of the second crop, which, in most cases is the final one, and is therefore of no avail, for the outbreak would have equally ceased without this extreme measure.

To be successful, closure must take place before measles becomes prevalent, and more than that, before the first crop appears. It will be seen that much depends upon the judgment of the teacher, and that the record cards showing (*a*) those who have had measles before admission to the department; (*b*) those who suffer, and the date, whilst scholars of this department; (*c*) those who leave the department and are not known to have had measles, would be invaluable, and quite worth the trouble of keeping if only to help in keeping up school attendance. The teacher must view the matter from a broad point of view, and realise that a few temporary absences may ward off a sweeping epidemic, involving the non-attendance of whole classes. Now that the so-called epidemic grant, formerly made under the Elementary Education Code, is done away with, it is all the more necessary that he should be alert.

Such charts would be of inestimable value when a question of school closure arose. At a glance one could tell how many in each class had had measles, and to what extent it was likely to spread.

Influenza.

Influenza, also, usually commences with a cold in the head; but it may be distinguished from measles by the sudden way it

comes on, the rapid rise in temperature and the pains and aches which accompany it. Influenza is very infectious and has an incubation period of about two days. When there is an epidemic in the district, the mere fact that a child has a cold in the head should be sufficient excuse for sending it home to bed. The real cure for influenza is bed.

Whooping Cough.

Whooping cough presents the same difficulties as measles, inasmuch as in its early stages it seems merely like an ordinary cold and cough, although all the time it is highly infectious. Here again the unconscientiousness of parents increases the difficulty of dealing with these cases. The only thing a teacher can do, if a child has a cough severe enough to make him vomit or whoop, is to send him home. The tendency of children with whooping cough is to double themselves up, or to bury their heads in something when the spasm of coughing comes on.

Scarlet Fever.

In a well-marked case there is typical sudden onset with high fever, vomiting, headache and sore throat; a red rash begins to appear on the chest within twenty-four hours. The patient is usually too ill for even the most indifferent mother to send it to school. The onset may, of course, occur while the child is attending school, when it should immediately be sent home. Mild cases, however, occur, and have been particularly frequent in recent years in this country. These are sent to school, for the fever is not high, the sore throat slight, and the child does not feel very ill; but it will be very apt to infect others in the class who are susceptible.

The value of a health register in this disease is also great. Those who have not had scarlet fever will be carefully watched for the first signs. It used to be considered that infection was most likely to be disseminated during the peeling stage, but more to be dreaded are convalescents with discharging ears and nostrils. It has been frequently seen that cases going into hospitals with scarlatina have reappeared as diphtheria carriers. For scarlatinal cases with discharging ears and nose, a stay in a convalescent home when they leave the hospital, and before they return to school, is desirable.

Diphtheria.

Diphtheria is unfortunately believed to be always a severe disease accompanied by very marked and serious symptoms, but the main risk of spreading infection arises, not in connection with the severe cases, but with (1) slight cases sent to school while actually suffering from the disease, and (2) the return of a child to school before its throat is free from infection.

Much has been done of late to check the spread of diphtheria in London schools, the object being to prevent an outbreak from going beyond its initial stages. The method adopted is to examine bacteriologically a portion of the mucus from the throat and nose of all children showing clinical signs of mild diphtheria, *e.g.* nasal discharge, enlarged cervical glands, undue pallor or ear discharge. With regard to this, the teacher can do much by vigilance, and by reporting suspicious cases to the Medical Officer of Health, especially in children whose attendance record shows suspiciously long absences.

The most dangerous age for the spread of diphtheria is between four and seven years. The blood of adults in this country contains a certain quantity of antitoxin. Probably children between four and seven are in an intermediate stage in which, having lost the protection acquired at birth from the placental circulation, they are not able to produce the antitoxin set up by subpathogenic doses of diphtheria bacilli. Diphtheria is a personal disease, and spreads only by personal contact.

Those who spread the disease are:

(1) Healthy children, who, without themselves suffering from it, transmit the diphtheria bacillus they have acquired from contact with one suffering from it. These are termed carriers.

(2) Children who have the disease themselves. These may be classified as (*a*) those who have clinical signs of mild diphtheria, but who are not ill enough to cause the parent or teacher to forbid them school; (*b*) those who have had a slight unrecognised attack, and are sent back to school in an infectious condition; (*c*) those who have been treated for diphtheria, but have been allowed to return without a bacteriological examination or a sufficiently long convalescence.

Of these, the most serious are the carriers, who, owing to the difficulty of detecting them, sow the diphtheria bacillus broadcast. On account of the varying time during which bacilli continue to exist in the nose and nasal passages, no time limit can be fixed for patients to be re-admitted to school: the one safeguard is bacteriological examination. On account of carriers, school closure for diphtheria is practically useless.

Small-Pox.

As a rule, a child attacked by small-pox is too ill to attend school. But as in diphtheria, there are mild cases which are infectious, and may give the disease to others in a severe form: this is called varioloid, or modified small-pox, in which the only evidence of the disease may be a few pimples on the forehead. It generally occurs among the imperfectly vaccinated. The re-vaccination of scholars at the age of ten would render an epidemic of small-pox impossible. The importance of vaccination should be taught in all schools, and the advantages of re-vaccination explained.

Chicken-Pox.

In chicken-pox there are scarcely any premonitary symptoms before the pimples appear. It is infectious during this stage, and is therefore very apt to spread through a class. It is a mild disease as a rule; but it must be remembered that there is a risk of mistaking a mild attack of small-pox, modified by vaccination, for chicken-pox.

Tuberculosis.

In tuberculosis there are variations, both as to the susceptibility of the subject and the virulence of the tubercle bacillus, and these two facts account in part, for the very varying degree of severity of the affections produced by the tubercle bacillus, under varying circumstances. Another factor is the part of the body infected.

For practical purposes we must distinguish sharply between tuberculosis of the skin, glands, joints and bones, intestines, lungs, and brain. Tuberculosis of the skin is a disfiguring but comparatively mild disorder; of the glands more serious; of the joints and bones still worse; of the intestines or lungs more severe and dangerous to life; of the brain almost always rapidly fatal.

Children are liable to all forms, but particularly to tuberculosis of the glands, bones, and brain, organs which usually escape in the adult. They suffer also from tuberculosis of the lungs, consumption, and it must be recollected that a single child affected with consumption of the lungs may infect many others, and that the infection may settle on glands, bones, lungs, or brain, according to the special susceptibility of the individual child thus exposed to infection.

The indirect predisposing causes of tuberculosis are heredity, overcrowding, insanitary dwellings, want of light, fresh air and proper food, and unhealthy employments. Determining causes are the inhalation of dust containing germs from the dried expectoration of consumptive patients; and also the presence of the tubercle bacillus in milk or meat.

In the London County Council School Management Code, issued April, 1904, under Article III. (Sanitary Condition of Schools: cleanliness of children, infectious diseases, notification, symptoms), Clause C (IX.), we read:

> Consumption is to be regarded as dangerous, and sufferers therefrom must be excluded if this disease is accompanied by coughing or spitting.

It would appear, from the numbers of cases of children with tuberculosis scattered in elementary schools, that teachers do not carry out the above rule. Until we have a system of daily medical inspection in schools, the teacher must cultivate a sanitary conscience and try to act in the wisest way for the general community. His duty will be to watch for cases of consumption of the lungs, and to send them for medical examination. A consumptive child may be easily suspected: the high temperature, the flushed cheek-bones, the gradual wasting and the cough will afford sufficient grounds. The misfortune is that excluding a child from school, means sending it back home, into the very conditions which gave it its illness: for in England sanatoriums for the treatment of tuberculosis in young children are badly wanted. In France numbers of sanatoriums of this kind exist where children are admitted and treated from the age of two. Their health is built up by nourishing food, an open-air life, and twelve or fourteen hours sleep. Boys and girls pre-disposed to tuberculosis are often saved from that disease by undergoing the same simple treatment for a time, and when

PLATE XVI.

To Shew Good and Bad Attitudes in Sitting. (*From Photographs taken at the Institut Marey, Paris.*)

Plate XVI.

A B

C D

Attitudes bad and good.

children actually attacked are sent in the earliest stages, a cure is nearly always assured.

As far as the child itself is concerned, under existing circumstances in England he is, in all probability, better off at school than at home. But the great responsibility of the teacher arises with regard to other children, thrown into contact with the tuberculous child; it may infect numbers of others, and in them the disease may take many different forms. Therefore he must not hestitate to ask that the child be removed.

The teacher must understand the predisposing and determining causes of tuberculosis, in order not only to detect existing cases, but to remove the causes which dispose children to contract the disease: prevention should be his highest aim.

In the prevention of consumption, fresh air plays the most important part. It not only diminishes the risk of infection through specifically contaminated dust, but it prevents all the evil consequences of breathing close air for many hours daily, the anæmia, laxness of tissue and general debility, and the imperfect expansion of the lungs, all well recognised pre-disposing causes of tuberculosis. Pulmonary consumption being essentially a disease of confinement and indoor life, the treatment for it is the open air. The old-fashioned methods of shutting up windows and doors, and remaining in a room with a big fire for lung troubles and colds, has given place to a system of open windows, even in the severest cases.

Pre-breathed air conduces to anæmia, fatigue and general debility, and therefore to consumption. Bad positions at desks, tending to narrow the chest capacity during drawing and writing, are also predisposing causes (Plate XVI.); they lead to insufficient breathing, loss of weight and malnutrition. The dust-laden, ill-ventilated school-room irritates the air passages and lungs, the dust, if there are children in the class with phthisis, being contaminated with the tubercle bacilli. It should be plainly understood that the expectoration of children suffering from consumption, if allowed to dry on the floor, the walls or handkerchiefs, is soon pulverised, and infects the air; as long as it is moist there is little danger. The discharges from tuberculous diseases of bones and joints may also infect the air after drying.

The body is helped to resist disease by everything which improves

nutrition; enough wholesome food is the first necessity, but it is useless without adequate muscular exercise, such as games, gymnastics and swimming; singing may also be included. Breathing exercises in the open air in the school-yard, properly done through the nose, have a most marked effect on the lungs and circulation, and should be repeated several times a day; practised in a room with foul air they are injurious.

Every child should receive simple instruction on the subject of tuberculosis, and habits of cleanliness in relation to it. None are too young to learn that spitting is a dangerous and disgusting habit, for which they will be punished if caught in the act. They can also be taught the danger of stooping over work, the importance of brushing their teeth, and of keeping the skin healthy by means of soap and water. Let it be realised that children from the earliest age can contract tuberculosis; that the prompter the measures taken, the greater the chance of recovery. And if in England we have as yet only gone in for the treatment and isolation of cases far advanced in the disease, the day will come when prophylactic measures will be everywhere employed. No one can do so much for this greatly needed reform as teachers, by never tiring of pointing out cases occurring in their schools, and demanding proper treatment for them. And meantime there are philanthropic bodies who might be persuaded to interest themselves in some of the cases. Great good must result in time from such teaching, although, until the feeding problem is solved and we have sanatoriums for unfit children, the good can only be partial.

Disinfection.

After an infectious illness it is necessary to disinfect everything which may have retained the germs of the disease. To disinfect means to destroy infection, *i.e.*, to kill the germs.

The natural means for doing this are fresh air and sunlight, but as it is not always possible to procure these elements, artificial means are employed.

The artificial methods commonly used are heat and chemicals.

Disinfection by Heat.

In order to disinfect effectually by heat, such a high temperature must be employed that germs cannot live in it, and every part

of the article must be reached. In order to encourage conscientious disinfection the process should be simple, rapid and cheap, and should do the least possible harm to the furniture, etc., of the house, while being at the same time as thorough as possible.

Boiling.—One of the easiest and most economical mediums for killing germs is soap and water. Soap is an excellent microbicide, its power varying according to the proportion of alkali contained in it. A solution of 10 per cent. will destroy in a few minutes the bacilli of cholera and typhoid fever; the action is hastened and rendered more sure by raising the temperature of the mixture. The addition of antiseptics does not increase the power of soap and water. Here then is a method of disinfection which can be employed by the poorest householder: but unfortunately only as regards linen or cotton fabrics.

Disinfection by steam, or air saturated with steam under pressure, must be resorted to for such things as flannels, blankets, woollen clothes, mattresses, carpets and all such fabrics as would be injured by boiling.

Hot air does not answer, because it does not penetrate into the fabrics. The air contained in the meshes of woollen stuffs is very hard to move, and a temperature sufficient to kill germs on the surface of a blanket or mattress would be insufficient to destroy those enmeshed in them. Thus, to kill such germs the temperature would have to be raised so much, that the outer surfaces would be scorched before the inner could be reached.

Steam under pressure penetrates much better, and a much higher temperature can be used; during the process of condensation a vacuum is produced, by which the air in the woollen material is displaced and forced to circulate. The temperature of the steam should be 115° C.; half an hour will suffice. To disinfect by steam requires special appliances: it should be remembered that the sanitary authority is bound to do it free.

Chemical Disinfection.

There is a great deal of popular misapprehension, owing to the distinction between the terms deodorising and disinfecting not being properly understood. To deodorise is to destroy or to conceal an unpleasant smell, by the employment of some sub-

stance which has a stronger smell than the unpleasant one. The sprinkling of disinfectants, such as carbolic, has this effect: it conceals a bad smell. Disinfection goes much further than this; it destroys the organic matter which causes the bad smell, and with it kills the harmful germs, which go on living in spite of endless deodorising. Many people still consider that the air of a room is kept pure and healthy by putting in one corner of it a saucer of carbolic, or permanganate of potash. It is only necessary to study the circulation of the air to know what a fallacy this is, as is also the burning of pastilles. Sulphurous acid gas, made by burning sulphur, used to be almost universally employed for disinfecting rooms, but it has many disadvantages, and the best gaseous disinfectant for the purpose is formalin and formic aldehyde vapour. The room is carefully sealed, and the duration of exposure should be four or five hours. For large rooms special apparatus is best, but for small rooms the alformant lamp is employed, 20 to 40 paraform tabloids being used for every 1000 cubic feet of space. The room should afterwards be thoroughly ventilated, and the floor and all paint be washed with water containing some non-poisonous disinfecting substance, such as izal, 1 to 100. Painted walls should be washed or sprayed with chloride of lime, 1 per cent.; or formalin, 2 per cent.; or izal, 1 per cent. This is often done in addition to the gaseous disinfection. It is not easy to disinfect wall-papers without spoiling them. The furniture, books, boots, or other articles likely to be damaged, or which cannot be dealt with by steam disinfection, may be sterilised with formalin while the room is being done.

X.—PERSONAL AND DOMESTIC HYGIENE.

The Skin—Structure of the Skin—Perspiration—Cleanliness—Body Heat—Clothing—Infant Rearing—Human and Cow's milk Compared—Condensed Milk—Proprietary Foods—Clothing—Sleep—Bathing—The Cleanliness of the House.

The Skin.

The skin consists of two coats, the dermis, or true skin, and the epidermis, or scurf skin; beneath the dermis there is, in nearly all parts of the body, a layer of fatty tissue which fills out the contour. The scurf skin consists of small cells or scales densely packed together; it has no blood vessels. The true skin contains much elastic tissue, and is richly supplied with blood-vessels, the blood in which, showing through the scurf skin gives the bright pink complexion of youth. The true skin also contains a multitude of nerves, and many of these end in little oval bodies, the tactile corpuscle, in which mainly the sense of touch resides; it contains, also, two sets of glands. First, the sweat glands, little coiled tubes of which there are altogether at least two million, and as each is about a quarter of an inch long, each person has seven or eight miles of them; they are, or ought to be constantly at work, although in cold weather the perspiration is insensible. The other glands are the sebaceous glands which secrete an oily substance. The outer layers of the epidermis are constantly being thrown off in invisible scales, and this natural process is favoured by the secretion of the sebaceous glands; and this keeps the scurf skin soft and supple. The hairs grow from a root at the bottom of a tube, or follicle, which goes down through the epidermis deeply into the true skin; into each hair-follicle opens a sebaceous gland; the oily secretion from these keeps the hair soft and glossy. In addition to the nerves of touch, another set of nerves go to the blood-vessels and regulate their size. When the little arteries, with which the skin is so closely

set dilate, it flushes, when they contract, it is blanched. The face flushes from heat, and becomes pale when the body is chilled; similar changes in the circulation are constantly taking place in the skin of other parts, and it is in this way mainly that the temperature of the body, which is practically the same in the tropics and in the Arctic regions, is regulated. When the air is warm, more blood flows through the skin where it is cooled, and if this does not produce sufficient effect, the perspiration is increased, and by its evaporation still more rapid cooling takes place. Some people seem to think of their skin as a mere covering, like the leather on the back of a book, whereas it is a most important living organ; it is, in fact, the largest gland in the body, not excepting the liver.

Habits of cleanliness in person and clothing are all important to health. The skin gives out perspiration and oil, and the dead scales from the epidermis collect on its surface. If these are not removed, the pores get clogged and the glands cannot act, additional work is thrown upon the lungs and kidneys, and these become diseased.

Soap and water are essential to health, and even where a real daily bath is impossible, everyone can wash from head to foot with soap and water, drying themselves briskly afterwards with a rough towel. Cold water is very stimulating, causing more rapid removal of waste products by the internal organs as a consequence of the contraction of the cutaneous blood-vessels, and producing an after warmth and glow, due to the increased activity of the skin. For actual cleansing, warm water is better than cold, so that an endeavour should be made to have a hot bath as often as possible. Now that so many public baths have been opened there is no excuse for dirt. Swimming may be described as combined bathing and exercise, and cannot be too much encouraged.

The teeth and gums should be brushed with a hard brush night and morning, care being taken to remove the food embedded between them causing decay. Soft tooth brushes are to be regarded as useless. Cold water and a simple antiseptic tooth powder are best; after use the tooth brush should be thoroughly rinsed in clean water, shaken and stood upright with the handle downwards. Children who are getting their second teeth are to be warned how

quickly they may decay, and how important it is that they should ask for them to be stopped at the first signs of decay. Bad teeth ruin the appearance and health, and in the case of boys who wish to join the army, destroy their chances of successfully passing the medical examination.

Cleanliness of clothes largely conduces to health. The under-clothing must be regularly and frequently changed, and the outer garments brushed and kept mended. Nothing makes clothes last so long and keep so neat as to brush and fold them up carefully at bed-time, the brushing to be done in the yard or at an open window, on account of dust. The hair should be thoroughly combed night and morning, and the scalp brushed hard for at least five minutes; this stimulates the skin, makes the hair grow and keeps it clean. The hair in a healthy condition is supple and glossy, and when well brushed will remain so. Curling pins, plaiting and waving spoil and break the hair. It is necessary to wash the head about once a fortnight; if soap is used care must be taken to rinse it out thoroughly, or the hair will be sticky; on this account the yoke of an egg beaten up in a little warm water, and used in place of soap, is more satisfactory.

The hands should be frequently washed, and always before meals. The nails must be neatly pared from time to time, frequently brushed, and never allowed to be dirty. Dirty nails destroy self respect, and the nails of the toes should be as much cared for as those of the hands. Habits of neatness can be acquired by everybody, and often the difference between a slattern and a tidy person merely depends upon the way in which the clothes are put on and the hair dressed.

Body Heat.

A thermometer is an instrument for measuring the temperature. It is usually a glass tube with a reservoir or bulb at one end and a narrow bore. The bulb and bore are filled with some fluid which expands regularly when heated; in clinical, bed side, thermometers the fluid used is mercury. When the bulb is warmed, the fluid expands and mounts up the bore of the tube; the height to which it mounts is a measure of the temperature. The thermometer was invented by Galileo and was improved by Fahrenheit, who devised the scale still in use in this country. On his scale the freezing point

of water is 32 degrees, and the boiling point 212 degrees. There are, therefore, 180° between freezing and boiling point. On the centigrade scale, now generally used for scientific purposes, the freezing point of water is taken as zero, 0°, and the boiling point as a hundred degrees, 100°. Centigrade degrees can be converted into Fahrenheit by multiplying by 9, dividing by 5, and adding 32.

The temperature of a warm blooded animal is always nearly the same, whatever the temperature of the air, whether in winter or summer, in the tropics or in the arctic regions.

The temperature is usually taken by placing a clinical thermometer in the armpit or mouth. The temperature thus registered, is a little lower than the true temperature of the internal organs. The normal temperature taken in the armpit is about 98·4° F., or 37° C., in the mouth about 98·9° F., or 37·2° C., the closed mouth being, in a certain sense, an internal organ. The normal temperature of the blood is about 100° F., or 38° C. The temperature of the body in health shows a slight variation during the twenty-four hours: early in the morning it is a little lower, late in the afternoon it is a little higher than 98·4° F., which has been taken as the normal or mean temperature. The following table shows this daily variation:

Daily Variation of the Temperature of the Body in Health.

6 a.m.	98·0° F.	36·7° C.
10 a.m.	98·4° F.	37·0° C.
2 p.m.	99·3° F.	37·4° C.
6 p.m.	99·5° F.	37·5° C.
10 p.m.	99·1° F.	37·3° C.
2 a.m.	98·5° F.	36·9° C.

This table affords only a general indication of the character of the daily fluctuation. The actual temperatures show differences in different individuals; in some the lowest temperature is lower than 98·0° F., in which case the highest temperature will be below 99·5° F.; in others, the fluctuation is less, the difference being less than 1·0° F., instead of 1·5° F. as in the table.

In fever the daily variation is greatly exaggerated, and as a rule it does not descend to the normal at any part of the twenty-four

hours; in blood poisoning, however, it often drops below normal in the early morning and shoots up again during the day.

It is seen from this table that the temperature rises during the active hours and falls during repose. The rise may be considered to be in some part, at least, due to fatigue, and this opinion is confirmed by the fact that excessive physical exertion may cause the temperature to rise considerably above the highest point of the normal daily fluctuation. Mental exertion also causes a rise of temperature of the body that may amount to half a degree Fahrenheit. In young children, the rhythm of the daily fluctuation of the body temperature is very easily disturbed by small causes; this is particularly true of excitable temperaments.

The heat of the body is maintained by the consumption, oxidation, in the tissues of all organs, of the food after digestion and absorption. How large a part of the total quantity of food taken is used up in this way, is explained in the section on Digestion. The classes of food yielding nearly all the energy required for the production of heat, are the carbohydrates and fats. Increased activity of every organ is attended by increased production of heat, but this is especially true of the muscles.

The temperature of the body is regulated by the nervous system, and is determined partly by the rate of production, but mainly by the rate at which heat is lost from the surface of the body. The rate of loss is regulated by the nervous system, mainly through the skin. When the temperature of the air falls, the blood vessels in the skin contract under the influence of the vaso-motor nerves, the surface becomes pale, and the amount of heat lost is diminished. When the air becomes warm the blood vessels dilate, the skin flushes, and the amount of heat lost increases. With a still higher air temperature the skin begins to perspire, and the evaporation of the moisture withdraws heat rapidly from the body. The explanation of the perspiration produced by violent exertion depends on the same principle; more heat is produced, and the excess is got rid of by the evaporation of moisture. In childhood, the nervous heat-regulating system has not reached its full development; this partly accounts for the ease with which the temperature is disturbed. It must also be remembered that in a child, the skin presents a larger surface in proportion to the weight of the whole body than in the

adult, a circumstance which must increase the difficulty of controlling the loss of heat by the skin.

Clothing.

As from 80 to 90 per cent. of the loss of heat is through the skin, the question of wise clothing is naturally very important. Clothing should be chosen with a view to warmth without heaviness for the winter, and for coolness and lightness in hot weather; the material should not be so compact and thick as to prevent evaporation and perspiration, but should prevent as much as possible conduction and radiation of heat. The ideal material to wear next the skin is wool, for it is light, porous and warm, three very important properties. The body is covered, in order that the temperature of the air in contact with the skin may be as equal as possible during the different seasons of the year. There is a variation of at least 50° F. between the summer and winter temperature of the air, while, as has been said, the temperature of the body does not vary a degree above or below 98·5° all the year round; clothing is therefore a means of preventing too great a loss of heat, and should be regulated accordingly. The fact that indoor and outdoor temperatures vary considerably, is the reason for wearing extra wraps when going out. Tight clothing, tending to compress the organs should be avoided; for to be in perfect health it is necessary to allow the lungs, heart, and other vital organs free play.

Uneducated parents put their children into steel-boned corsets at the earliest ages, ignoring the fact that at the growing period of life their limbs and chest should be free to expand: corsets are quite unnecessary. Each girl should wear a flannel chemise, serge knickerbockers fitted to the waist with an elastic band, a low-necked overdress, with shoulder straps and a loose belt, and under this a woollen jersey in winter and a cotton shirt in summer. To the older girls should be pointed out the advantages of short skirts, apart from their neatness; disease and infection are spread by women who allow their skirts to trail along the pavements.

Porous clothing, because it allows the air to circulate freely round the body, diminishes susceptibility to cold. Women often have half a dozen thicknesses of non-porous clothing below the waist, weighing down the body and excluding air; air, when

retained in the meshes of a woollen fabric, is one of the chief sources of warmth.

Teachers should be firm in refusing to admit to their classes untidy children with ragged, dirty clothes. Apart from the moral degradation, there is the unhealthiness: children are much like plants, they cannot flourish under bad conditions. The elder girls and boys should be taught the dignity of neatness and the moral poison of dirt and untidiness.

Infant Rearing.

The proper care and feeding of infants during the first two years of their lives, is the most vitally important subject that can be taught to the elder girls. Born healthy, a child may generally be kept healthy by clean sensible feeding.

The mother's breast is its natural food, and all babies thrive best on that, provided the mother is healthy. When artificial feeding becomes necessary, the risk to the infant for the first four or five months is very great, for its organs were made to digest its mother's milk, and every other food is a foreign substance, that may or may not agree with it. The foods generally used in the artificial feeding of infants are cows' milk, condensed tinned milk, and various proprietory foods. Of these, cows' milk most resembles human milk; both are animal products, and consist of a living fluid with biological properties.

But although they appear to resemble each other very closely, there are in reality important differences; this is not surprising when the difference between the human and the bovine digestion is taken into consideration. The composition of human milk has already been discussed in the section on Digestion. It yields a soft curd, capable of being easily digested and assimilated; the human infant has one stomach. The milk of the cow yields a hard curd; the calf has four stomachs to enable it to digest it. The milk of each species of animal is specialised to suit the digestive system, rate of growth, nutrition and mode of life of that particular animal. In the following table the composition of human and cows' milk is compared.

Percentage Composition of Human Milk and Cows' Milk.

	Water.	Proteid.	Fat.	Milk Sugar.	Ash.
Human	88·7	1·6	3·4	6·1	0·2
Cows'	87·2	3·5	3·7	4·9	0·7

It will be observed that cow's milk contains more proteid and salt, and less milk sugar than human milk ; in this latter there is also a large proportion of lecithin, a phosphorised fat, a necessary element in the formation of the brain and nervous system of an infant. The calf does not require so large a proportion of lecithin as the infant, for it is born with its nervous system much more fully developed, and very soon leads the same life as its mother.

The soluble ferments present in milk, play a part in the healthy nutrition of an infant; they stimulate and regulate its nutrition, for the blood and digestive juices of the infant are relatively poor in ferments. Some scientists believe that milk from one species is, in a sense, poisonous to the young of another: an artificially fed baby has to produce an intestinal anti-body, before it can begin the work of digesting and assimilating its food, whereas the milk of its own mother contains anti-bodies derived from the mother, which not only favour digestion but are a protection from disease-producing bacteria.

Further, it is necessary in order to resist disease, that the cells in which the vital processes take place should be numerous and well nourished: for this, suitable material is needed, otherwise any gain in weight will be chiefly fat and water. The cells may be actually starving when the child appears to be fat, nor does it follow that it is either strong or healthy.

Human milk passes from the secreting gland direct to the baby's mouth in a practically sterile state ; the milk of the cow has to pass through so many sources of contamination, that it is usually in a more or less poisonous condition before it reaches the infant. When drawn from the cow milk is practically free from bacteria, but these soon get into it, principally through lack of cleanliness

about the dairy; milk is a good culture-medium for many bacteria, and in it they multiply with immense rapidity. Practically all the changes that take place in milk kept for any length of time, are caused by bacteria. They need not necessarily mean disease: indeed their wholesale destruction would be a great misfortune, as many are absolutely necessary: for instance, to certain bacteria in milk is due the success of cheese making.

If milk is kept in a warm room it soon becomes sour; this is caused by the growth in it of the lactic acid bacteria, very common in dairies, pantries, and kitchens; they attack the sugar of the milk, converting it into lactic acid with liberation of carbon dioxide gas; lactic acid curdles the casein which falls in loose, ragged clots. These bacteria are harmless, and before baking powder came into the market, sour milk was much used with bi-carbonate of soda in cake and biscuit making. Milk, as a rule, contains several species of bacteria, but it presents conditions so favourable to those which produce lactic acid, that after a few hours they greatly outnumber the other species, and often form ninety-nine per cent. In the absence of the lactic acid bacteria, those which attack the fat and proteids of milk, produce rancidity of fat and putrefactive changes in the proteids.

There are many ways in which bacteria get into milk: from the cow's udder; from the cow's body: on a single cow's hair several hundred bacteria have been counted, and in the manure and dirt which falls into the milk from an unbrushed and unwashed cow's body or udder, there are millions of bacteria per gram; from dust to be found in the byres, in dry hay, and in the milkers' clothes; from the milkers' unwashed hands; from unclean dairy utensils.

Milk should be cooled at once to below 45° F., or heated to a temperature high enough to destroy bacteria. It is usual now to cool milk at dairy farms immediately after milking, by running it over a refrigerator, an apparatus through which cold water is caused to flow: this stops the growth of microbes for the time, but if it is again allowed to become warm, these soon begin to grow again. In short, milk produced under dirty conditions will always contain large numbers of bacteria, and these will be increased during railway transit, at the milk dealer's, in the homes, and as it is given to the baby, in a poisonous long tube bottle.

Mothers should nurse their babies: if this is absolutely impossible, cow's milk is the best available substitute for the mother. There are only two alternatives: condensed tinned milk and proprietary foods. Milk is condensed by heating it to near boiling point, and then removing a large portion of water by boiling at a low temperature in vacuum pans. As a rule some cane sugar is added, and the mixture is poured into tin cans and hermetically sealed. Much of the condensed milk in the market is made from separated milk, and is absolutly destitute of fat: infants fed on it are slowly starved. Most brands of condensed milk contain too little fat. Condensed milk is deficient in anti-scorbutic properties, and contains an excessive amount of cane sugar. Infants fed on it are very liable to suffer from rickets and scurvy.

After all, condensed milk, before being preserved, was exposed in the dairy to the same sources of impurity as the milk sold in an uncooked state. The process of tinning kills many of the bacteria, but not as a rule all, for most condensed milk is not sterile; further, if the milk has begun to decompose before being tinned, though most or perhaps all of the bacteria may be killed during that process, the products are not dissipated. Finally, when a tin is opened the microbes of putrefaction find their way into it, and quickly render the contents dangerous. Unfortunately this form of food is much used for infants by the labouring classes.

Milk is sold dried, either alone or mixed with various cereals. These preparations are all open to the objection that they are not fresh foods, and are unsuitable to form the entire diet of an infant, since they tend to produce anæmia and scurvy. A further objection to their use is that they are deficient in essential elements other than starch, more or less modified, many of them being ground biscuit or baked flour.

If an infant has to be artificially fed it should get pure milk, milk and water, or milk and barley water, according to its capabilities of digesting. Some infants are more feeble than others, and for a time may require half milk and half water: it will be safer to boil all milk. At first a meal should be given about every two hours, but as the digestion grows stronger the proportion of milk should be increased, and, as the child takes a greater quantity, the meals can be given every four hours: a fixed interval should be observed and

the child on no account fed oftener. No other food need be given until nearly a year old; the salivary glands will then be in good working order to act on starchy foods, and some of the milk meals may be supplemented by such things as biscuits, bread and butter, and simple milky puddings.

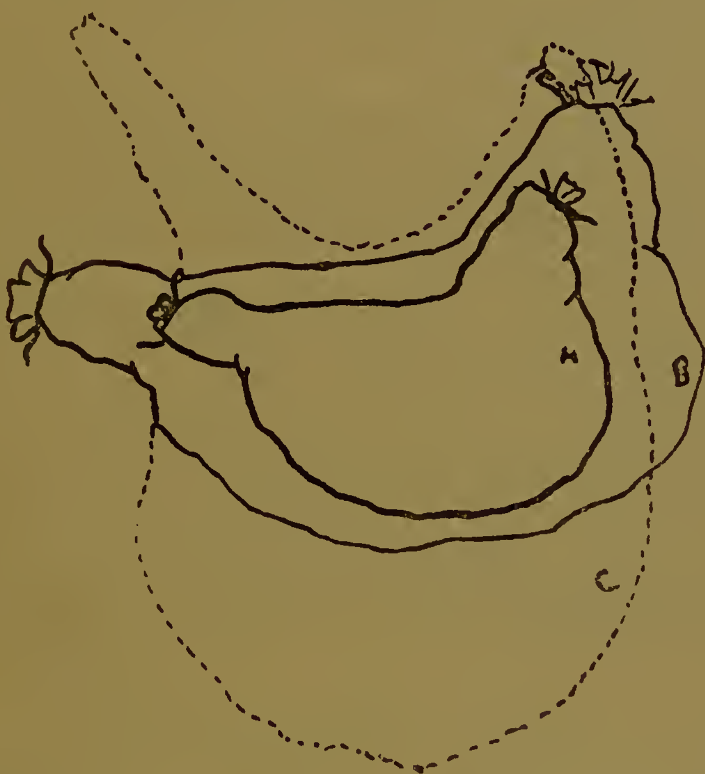


Fig. 25.—Diagram to Illustrate the Capacity of the Infant's Stomach.

A, the smallest outline represents the stomach of an infant, aged five days (capacity, 25 c.c.; less than 1 fl. oz.); B, the intermediate outline represents the stomach of an infant, aged twelve months (capacity, 120 c.c.; about 4 fl. oz.); C, the dotted outline represents the dilated stomach of a rickety infant, aged seven months (capacity, 300 c.c.; about 10 fl. oz.)—(All ×).—After Rotch (*Keating's Cyclopædia*).

The child should not get meat or green vegetables until after the second year, and it is a mistake to give it scraps of food while grown up meals are going on. This dangerous and stupid practice unfor-

tunately goes on to a large extent from ignorance or mistaken kindness.

It is important to weigh the baby once a week and to keep a record of the amount gained: if the gain is steady week by week, and if the infant's flesh feels firm and healthy, it is an assurance that its food is agreeing with it. The clothing will be weighed separately and deducted from the total number of pounds. An infant should have doubled its weight at five or six months, and trebled it at fifteen or sixteen months.

Teething commences at the sixth or seventh month, and is usually completed when the child is two and a half years old. Although there is some variation in the time, any great delay in teething may be considered as a sign of faulty nutrition or constitutional disease, for example, rickets (p. 72).

It is unwise to allow infants to stand before a year, and crawling is to be discouraged: the bones are in such an undeveloped condition that deformity is easily produced.

Clothing must be warm, loose, and of material which can be easily washed. The circulation is weak, and infants soon get cold, so that they should wear flannel always next to their skin, and the feet must be kept warm by woollen shoes. Flannelette is a bad substitute for flannel: flannel is worth the extra cost, for it will last a long time soft and good by careful washing, in cool water with a little ammonia in it. The custom of socks, and frocks with short sleeves and low necks, is most unwise, and the flannel binder is best continued at all seasons, until the child is several years old.

Scrupulous cleanliness must be observed in babies and young children; a feeble infant may have to be washed piecemeal for a few weeks on the mother's lap, but for a healthy, strong baby, one bath or two baths daily are to be recommended. The best temperature for the water is about 90° F., and it is a good plan to cool the bath while rinsing the child, by adding cold water. As it grows older, a strong child will enjoy a cold bath and be stimulated by it, but if it appears to dislike it force should not be used: in any case quick drying, rubbing, and powdering follow the washing.

A healthy infant sleeps eight or nine hours at night and a good deal during the daytime: if it happens to sleep badly, it must on no account be fed to quiet it, as this will injure the digestion and

cause it to sleep worse. A separate bed for an infant is essential: it is better and healthier for it, and many deaths occur annually from mothers overlying their children. Curtains are unhealthy and the cradle must not be deep, otherwise when the child is covered by blankets, which should constitute the bed covering, the free current of air is impeded. As the child gets older, it will continue to sleep in the middle of the day if it is sent to lie down; this practice is very valuable, and should be continued until the fifth or sixth year.

A baby can be trained to cleanly habits from its earliest days; it can also be trained to go to sleep without rocking, to lie good in its cot when wide awake, and to expect feeding only at fixed intervals. The mother who takes a little trouble at first will save herself and the baby much later on.

The rule for cleanliness applies to all young children. It is complained that in the lowest standards, children, especially boys, are sent to school unwashed and with very dirty clothes, and in the poorer schools teachers would find it wise to have a special time on the time-table for the inspection of the children's teeth, eyes, ears, noses, hair, clothes, etc.; each teacher to have a record book, and each child to be tested with regard to these points and entries made. The defects should be pointed out to the school doctor, and the parents notified. This plan would oblige the mothers to keep the children clean and tidy.

The Cleanliness of the House.

In houses which are kept clean, airy, light and dustless, germs do not flourish.

It is in damp, dark, stuffy dwellings that the microbes of disease lurk; every particle of dust contains thousands of them, and the longer it is allowed to lie the more dangerous it becomes. Dry sweeping of floors and carpets is bad work, for the dust is raised without being really removed. Before sweeping, carpets should be freely sprinkled with tea leaves first rinsed in cold water to remove the brown staining matter. It is not necessary to be always scrubbing floors and saturating them with water; it is sufficient to clean them with damp flannel or cloths, after first scrubbing them with a soapy brush, out of which most of the water has been shaken.

The cloths must be frequently dipped in the water and wrung out, the water being often renewed. When the weather permits, it is good to throw windows and doors open, so that air and light may supply hygienic drying. In cleaning paint, the use of a brush and soda should be avoided; warm soapy water and a flannel are sufficient, with a cloth for drying purposes.

Attention to apparently trivial details in a house greatly assists in the prevention of disease. Thus wall paper ought to be smooth, so that dust particles may not adhere to it; it can be brushed and occasionally cleaned with stale bread. Bed curtains, valances, thick window curtains, antimacassars or cloth table covers, are all merely dust traps. For the same reason, stained floors with rugs easily taken up, and shaken outside the house, are far more sanitary than carpets nailed to the floor.

Darkness acts on a human being as on a plant: put a plant in a cellar for a week and it will come out pale and sickly looking. In out-of-door life, the sun and the oxygen in the air supply health to plants and human beings, and destroy microbes: the same thing applies to sunlight and air inside the house. Windows kept clean and thrown open supply light and air, provided the blinds are kept drawn up as high as possible and curtains avoided.

It has been pointed out, under ventilation, that air goes out by the top of the window and comes in at the bottom. To keep in health, bedroom windows must be left open top and bottom, both day and night, so as to carry away impure air and bring in a fresh supply. Besides this, a fireplace is necessary to cause a current of air. An open door, which some people employ as a means of ventilation, allows the used-up air of passages and basement to be received by way of fresh air into the bedroom, unless the passage windows are kept open all night. People who understand the value of a good air supply use both window and door, provided the bed is out of the draught. The wider open a window, and the less concentrated therefore the current of air coming in, the less risk there is of catching cold. Night air is as fit to breathe as day air.

Draughts are to be avoided, although many people can harden themselves to them. A draught may be described as a current of air which, striking some parts of a person sitting directly in it,

results in loss of heat in that portion of the body. Draughts are especially dangerous if a person is very hot, or in a state of perspiration; the blood vessels are contracted and the blood driven from the surface to the internal parts; if some of these are weak, bad consequences may result.

In order that pure air may be blown in through the windows of a house, care must be taken that in the back yard such things as the dust-bin are kept as clean as possible. House refuse is chiefly composed of decaying vegetable and animal matter, which, by the end of the week gives off poisonous effluvia. In towns refuse cannot be buried as in the country, but it is possible to dry all the animal and vegetable matter and then burn it. Provided it is dried, it does not cause a bad smell while burning. The best kind of dust-bin is a galvanized iron pail or tub, with a tight fitting lid, and this should be kept as far away as possible from the larder. It is generally believed that waste water from baths, lavatories and sinks is harmless, but if the pipes are not rinsed by cold water, the fat in the soap and scraps clings to the sides of the pipes, where it decomposes and gives off effluvia that spread through the house.

All ceilings and walls of kitchens and outhouses should be whitewashed from time to time, and in some towns whitewash and brushes are supplied free of charge.

Things should not be hidden away from the sanitary inspector. He should be looked upon as a benefactor, for he can see to drainage, disinfection, and nuisances.

Accumulations of dirty linen, old rubbish and dirty slop pails are unhealthy, and must be avoided.

In order that the work in a house may be methodically managed, besides the ordinary every-day routine, it is a good plan to map out some scheme of work for the week, so as to get through such things as washing the clothes, ironing and mending them, cleaning out rooms, etc., in an orderly and methodical way.

It is always wisest when furnishing a house, to buy at first only such things as are absolutely necessary. These can be gradually added to, care being taken never to buy anything that is not really needed.

To sleep on the floor is unhealthy. The free circulation of air round the sleeper is interfered with, and dust and noxious gases

from the floor are breathed in. Iron bedsteads with chain mattresses are the cleanest and most satisfactory. Terrible disclosures have been lately made with regard to the bedding commonly in use. The mattresses, used by nearly 80 per cent. of the labouring classes, are said to be stuffed with foul rags shredded into stuff known as flock, without any attempt at disinfection or cleansing. Bacteriological examination shows that the numbers of bacteria which exist in these mattresses, even when new, are larger than those contained in the crude sewage of Glasgow. Every time the beds are made, this dust is shaken about the room. The difference in cost between a mattress stuffed with cleansed woollen millpuff at 10s. per cwt., and the dirty, unwashed wool flock now so much used, is only about 2s., and as beds are generally only bought once in a lifetime, this small extra initial cost would not be missed. The same applies to pillows. Cheap blankets are also a mistake, for they give very little warmth.

THE END.

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